[COMMITTEE PRINT]

TECHNOLOGY POLICY TASK FORCE

TECHNOLOGY POLICY AND ITS EFFECT ON THE NATIONAL ECONOMY

REPORT

PREPARED BY THE

TECHNOLOGY POLICY TASK FORCE

TRANSMITTED TO THE

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SCIENCE, SPACE, AND TECHNOLOGY
HOUSE OF REPRESENTATIVES

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LETTER OF SUBMITTAL

House of Representatives,
Washington, DC, October 19, 1988.

Hon. Jim Wright,
Speaker of the U.S. House of Representatives,
Washington, DC.

Dear Mr. Speaker: By direction of the Committee on Science, Space, and Technology, I hereby submit the Committee's study report which includes an associated policy statement on technology. The report was approved by the Committee on October 13, 1988. The study and preparation of the report was carried out under the direction of the Technology Policy Task Force between April 23, 1987 and October 13, 1988.

Sincerely,

Robert A. Roe,
Chairman.

Enclosure.

LETTER OF TRANSMITTAL

House of Representatives,
Committee on Science, Space, and Technology,
Washington, DC, October 13, 1988.

Hon. Robert A. Roe,
Chairman, Committee on Science, Space, and Technology.

Dear Mr. Chairman: On your instructions, the Technology Policy Task Force under the leadership of Congressmen Buddy MacKay and Ron Packard carried out an extensive study on technology, in a painstaking manner. I am forwarding the results of that study in the form of a report and associated policy statement.

I believe the report and the associated policy statement provide a means to carry out research and development so that industry and government can cooperate more effectively in the future. Such cooperation is the primary answer to making the U.S. more competitive.

Sincerely,

George E. Brown, Jr.,
Acting Chairman, Technology Policy Task Force.

NATIONAL POLICY ON TECHNOLOGY

by

The Technology Policy Task Force

of the

Committee on Science, Space, and Technology

POLICY STATEMENT

Background

When the Technology Policy Task Force began this study in April 1987 there was grave concern that the United States was losing its share of the international market. Foreign made products from the "smoke stack" industries as well as high-technology products were appearing on the U.S. marketplace in increasing quantities. Competitiveness became a buzzword in Washington; constituents argued for protection from foreign producers. The Technology Policy Task Force was determined to sort through these matters and recommend an appropriate role for government.

America's economic problems began in the 1960's when productivity growth rates began to decline while labor and management wages continued to increase. Manufacturing machinery aged and industrial managers often failed to make timely investments in new plants and equipment. In the 1970's federal and state laws and regulations were instituted in response to environment, energy, health and public safety issues. The measures designed to deal with these worthy issues became complex and costly to industry in both dollars and time. Litigation increased; product costs climbed; quality stagnated. High inflation with rising labor and materials costs exacerbated matters. U.S. industry simply lost control of many markets as other industrial nations began to sell high quality products at competitive prices.

The Mission of the Technology Policy Task Force

The mission of the Task Force was to employ its knowledge of government and technology and suggest a policy which would help the U.S. maintain a leadership position in technology. Success in this is necessary to maintain the standard of living to which we are accustomed. While some shift from manufacturing to service industries may occur, a strong domestic manufacturing base is essential to a strong economy and military security.

The scientific and innovative skills of U.S. entrepreneurs are second to none. Others are improving and perfecting our inventions and beating us to market with high-quality, low-cost products. Why is this happening? What must be done to assure that U.S. science and technology discoveries are more effectively converted to high-quality, U.S.-manufactured commercial products that compete in the U.S. and foreign markets?

The Task Force obtained information from government sources and from the private sector through Congressional Hearings and written comments from its 24 Member Advisory Board. An extensive number of reports and documents from public and private sources were utilized. Conclusions were based on these reports as well as studies prepared by other agencies and institutions including the Office of Technology Assessment, the Council on Competitiveness, the General Accounting Office, the Congressional Research Service, the National Academy of Engineering, the American Society of Mechanical Engineers, and others.

The Task Force received many explanations for losses in U.S. market share:

- decreased product sales induced initially by the high value of the dollar are difficult to reestablish;
- competition from other countries has increased;
- the world debt crisis resulted in a loss of markets in debtor countries;
- high capital costs have inhibited corporate long-term investments;
- low savings rates led to high capital costs; and
- certain commodities have been oversupplied.

In some areas, government policies, particularly in the tax and antitrust areas, have created the problem. In other cases, conditions were caused by factors which were out of U.S. control. For example, other nations that once depended on the United States for many of their products have since developed their own industrial capabilities including skilled work forces and modern manufacturing plants. Japan, Korea, Taiwan and others have become formidable competitors. In short, there is no single reason which explains U.S. losses in market share.

THE TRADE DEFICIT

While the lower value of the dollar has helped increase exports, it will not in itself remedy the trade imbalance. The United States is still losing more than $340 million a day in trade to foreign competitors. In spite of excellent research and development and impressive productivity improvements by some U.S. firms, there are still weaknesses in U.S. product development and manufacturing.

The Task Force considered many policy areas to reduce the trade deficit: trade; budget; technology transfer; government R&D priorities; engineering, mathematics, and science education; cooperation between government and industry; new centers for technology development; tax incentives; patent laws; and others.

TRADE DEFICIT AND PRIVATE INDUSTRY

It is clear that American firms must produce more products at home and they must sell more products at home and abroad if trade is to be brought back in balance. U.S. companies will respond to this challenge if the proper incentives are in place. Corporate management decisions are made to maximize profits and minimize risks. Many U.S. firms currently find that manufacturing products overseas has financial advantages over making them in the U.S. Many firms buy components from abroad and assemble products in the U.S. Some firms merely distribute and market foreign made products in the U.S. and elsewhere. If trade is to be rebalanced, the business environment in the U.S. will have to be changed to make it more profitable for U.S. companies to manufacture quality products here at home.

The Task Force believes policies that make it advantageous for industry to develop and manufacture products in the U.S. are superior to tariffs or other protection against foreign imports.

The Task Force recommends Congressional action to assure that other nations remove import barriers and suggests a continuing effort to negotiate fair trade agreements with other nations.

The Task Force believes government should not and can not prescribe programs for industry or even recommend areas of technology where industry should concentrate its resources. However, government already exerts influence on industry through a broad range of policies including: budget; trade; technology development; education; industrial regulations; tax and patent law; etc. The Task Force study includes references to these policies and a number of other issues. Legislation in the following areas is recommended.

NATIONAL POLICY ON TECHNOLOGY

Part One—A Joint Government/Industry Venture

While less than six percent of the federal budget is spent on research and development, this part of the federal budget, when combined with about the same level of investment from industry, fuels our economic future. For this reason, more direct use of government research and development funds must be made to support industry in the areas of product design, development and manufacturing.

An effective organization must be established within the government which would, with direction and guidance from private industry, participate in the revitalization of U.S. industries and assure their continuing strength.

This organization would perform the following functions:

1. collect and analyze data on advancements in technologies, market trends and the performance of industries throughout the world;
2. receive and accept guidance from private U.S. firms and labor;
3. determine the optimum use of U.S. resources for the support of technology development and productivity improvement;
4. advise the President and the Congress on program priorities;
5. evaluate the status of programs and report strengths and weaknesses to the President and the Congress; and
6. advise government agencies and Congress about regulations and government restrictions that inhibit economic activities. The organization would then report on the progress made in improving government procedures and regulations to Congress.

The Task Force reviewed four options to do this: a Department of Science and Technology; a change in the enabling language to expand the Office of Science and Technology Policy; a Council on Technology composed of representatives from industry and government; and a National Policy and Technology Foundation. The Task Force decided that it need not recommend a particular organizational structure because this would ensue from debate accompanying the preparation of legislation.

Part Two—A New Priority Mission for Federal and National Laboratories

The Task Force calls for opening up the National and Federal Laboratories to support U.S. firms in the areas of biotechnology, medical technologies, aerospace systems, computer systems, software development, artificial intelligence, electronics (including very large-scale integrated circuits), propulsion systems, advanced sensors, optical information processing, steel and aluminum processing, advanced materials, thin-layer technology, manufacturing automation, environmental hazard reduction systems, energy systems, mass transit systems, and other priority areas.

More flexibility must be granted for laboratory personnel to work directly with private firms, universities, and state and local governments without the delays inherent in "going through" Washington. To do this requires that more authority and responsibility be placed in the hands of laboratory directors.

Part Three—Research and Development Support for the Construction Industry

As part of the extension of government resources to private industry, the Task Force calls for exploring the potential for authorizing civilian-oriented research and development programs to the Corps of Engineers, which has a long history of developing equipment and construction methods. These programs would be directed toward supporting the U.S. construction industry. The Task Force discovered that construction industry investments in research on new equipment, construction techniques, and automation is far below the minimum needed to stay abreast of other industrial nations. Advancements in building materials on the other hand have been positive.

Part Four—Resurrection of U.S. Consumer Electronics Manufacturing Capabilities

The United States has virtually surrendered its consumer electronics manufacturing capability to other nations. The U.S. is not in a position to capture any appreciable part of the forthcoming market for high definition television (HDTV). With the recent sale of the GE and RCA consumer electronic divisions and the current offer of foreign firms to purchase the Zenith Corporation, the U.S. will be unable to participate in this new "high-tech" market. HDTV will then be dominated by Japan, France, the Netherlands, and to a lesser degree, Asian Rim Nations.

HDTV offers more than television with a clearer picture. This technology will pave the way for home interactive electronics retailing, education, and personal communications by tieing television and computers together.

For this reason, the Task Force recommends creation of a National Advanced Technology Center for Consumer Electronics. Founding a government-funded organization to undertake the development of advanced technologies essential to the next generation of consumer electronic products and manufacturing processes is recommended.

Part Five—Education of Tomorrow's Manufacturing Engineers and Managers

The information collected during the course of the study indicates that there are some general weaknesses in U.S. manufacturing practices. In contrast to Japanese firms, many U.S. firms cannot produce a high quality product in a short time. As a result, the Japanese are able to capture the greater share of a market. Not only can they capture a market, but they are particularly skilled at tracking market response so that they are able to furnish improved products before the competition has a chance to compete with the initial version of the Japanese product.

The Task Force attributes problems in U.S. manufacturing to a lack of interest in manufacturing operations on the part of upper corporate management. For example, in the U.S., financial incentives encourage engineers to work in design and then step into management. The financial rewards for a career in manufacturing are unattractive. In contrast, the top engineering graduates in Japan compete for employment in the large Japanese corporations where, according to Keikou Terui of the Ministry of International Trade and Industry in Tokyo, they *begin* their training. Engineers are then transferred from manufacturing to design and to other areas of the corporation. As a result of these varied assignments they become highly skilled across a broad spectrum of corporate activities. Eventually, they become experts at designing and making products that are high quality, low cost, and have high customer appeal.

While many U.S. colleges offer excellent courses in manufacturing, this field is generally "looked down on" in U.S. scientific and engineering circles. The hierarchy goes from basic and applied research scientist to design and development engineer, and finally at the bottom of the stack are manufacturing engineers.

To further complicate the problem, many corporate managers, highly educated and skilled in financial management, know very little about the products they make or how they are made. A partial reason for this shortcoming lies in the emphasis U.S. firms have placed on selecting their management from business school graduates.

For the above reasons, the Task Force recommends founding a National Institute of Manufacturing Engineering. This institute is to be founded on the basis of offers received from existing institutes, colleges and universities having assets in manufacturing.

Part Six—Elevating Skill Levels in the Useful Arts and Advanced Technologies

While the U.S. has made outstanding achievements in creating new jobs, the greatest challenge to America's international competitiveness lies in the education and training of its people. Emphasis is particularly needed on technical expertise directly related to product quality and improved manufacturing processes. This expertise may be lost in future years, since so many products consumed by Americans are manufactured abroad.

Our ability to increase the proficiency of American engineers and production workers is directly dependent on an adequate supply of high school graduates to enter college as well as industry.

State and local governments have placed increased emphasis on mathematics and science education, but significant improvements are needed to better prepare students to continue their education in engineering and technical fields.

The Task Force found serious problems in urban education. Without effective changes in urban schools, a significant proportion of our population will lack the skills needed to compete for jobs in high-technology industries. There are no "quick fixes." The problems of urban schools reflect more general societal problems. The Task Force supports the Carnegie Trustees' recommendation for a new National Urban Schools Program "similar in spirit" to the Rural Extension Act which helped farmers. While not reducing state and local responsibility for education, the program would provide additional federal support for basic skills programs, facilities, and other central city education programs.

The Task Force recommends a joint effort by the Committee on Education and Labor and the Committee on Science, Space, and Technology to develop legislation for "pilot" education programs in urban areas. A number of programs have shown evidence of making a difference: small school units, magnet schools, college scholarship programs, community support programs, and plans to encourage teacher and principal accountability. These programs constitute one step in addressing a complex societal problem which goes well beyond the education system. These pilot programs would provide information useful to all cities—as well as to states and the Federal Government—in setting future policies for urban education.

Closely associated with problems in urban education is the recent decline in college enrollment of students from low-income families. Because many minority youth come from low-income families, live in high-crime areas, and attend poor schools, they have low college attendance rates.

While the Task Force does not take a position on specific programs, we recommend that high priority be given to public policies which increase the access of low-income students to higher education.

REPORT ON TECHNOLOGY POLICY AND ITS EFFECT ON THE NATIONAL ECONOMY

by

The Technology Policy Task Force

of the

Committee on Science, Space, and Technology

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INTRODUCTION

The world is in one of the most extraordinary periods of its history. We are in an information age made possible by an explosion in technology. Every aspect of our lives is being touched by the rapid emergence of new technology. To remain in the forefront and reap the benefits of new applications of technology, we in the United States must take certain essential steps. Better education for all citizens, more effective practices for policy making, more efficient and pragmatic use of all our research and development resources, better management and cooperation between government and industry, more emphasis on living within our economic means as individuals and as a Nation, and revitalization of our work ethics are necessary to insure a prosperous future.

Over the past 50 years, hundreds of thousands of new and improved products and services were thrust into the market through technological innovation. No one can predict what will be brought to market in the future. Even the task of selecting "priority technologies" for government to support will be formidable. Such policy decisions should be made only within the framework of new modes of cooperation with industry, and with more refined analysis of global economic trends.

Many technologies show great promise for improving U.S. productivity and for making the U.S. an even better place to live. Biotechnology promises opportunities to enhance world food production and provide remedies for diseases. Advancements in artificial intelligence can provide vastly increased teaching capabilities. New products designed for recycling can eliminate many waste problems.

The Science, Space, and Technology Committee inaugurated the Technology Policy Task Force on April 23, 1987, to study the current state of U.S. technology, the ways in which various technologies could be strengthened, and how those strengths could be brought to bear on national problems. The Task Force was charged with reporting its conclusions and recommendations to the Committee. This report meets that mandate by providing background information and making recommendations intended to put technology to work for a better society and stronger economy. No attempt is made in this report to identify specific programs in which to invest. The intent here is simply to identify the economic conditions and government policies which influence our abilities to remain on the leading edge of technology.

While the Technology Policy Task Force tried to stay within the jurisdiction of the Committee on Science, Space, and Technology, it became obvious from the start that our progress in technology development is dependent on other sectors of government and the economy. For this reason, Section C, Effects of Government Policies on Technology, has been included.

Task Force Agenda

This report was prepared in response to the Task Force Agenda, dated June 1987. The following directions were contained in the Agenda:

> Although the American system still offers much more than any other society, not every prospect pleases. Many of our major industries have declined. Other industries are kept functional through direct government intervention. Some segments of the economy are seeking protection from foreign competitors who are striving to take over international markets. Meanwhile the national debt grows to more than 2 trillion dollars so that the annual interest on our debt is 15% of the federal budget, or roughly $150 billion. Thus, there seem to be portents of a national future that could be less affluent, less respected, and less influential in the community of nations.
>
> Thus this Committee must occupy a central role in the national examination of the United States as a technological innovator, a manufacturer, and a trader in high and low technology products.
>
> However, our Technology Policy Study must look also to broader issues and factors such as availability of capital, technical education, government regulation, and innovation, which must come together in order to advance technology in a sustained and consistent manner.
>
> The Technology Policy Study by the House Committee on Science, Space, and Technology should examine the relevant factors and develop agreement on the roles that Federal Government and the private sector can and must play in reaching viable solutions. The Study should establish what policies must be pursued by our government to ensure that the right environment for scientific research, technological development, marketplace success, and sustained growth is created and maintained.
>
> The proper role for the Federal Government in the process of fostering technology development is less well under-

stood, defined, or accepted than its role in support of scientific research. Yet it is technology, in one form or another, rather than science, that most clearly affects the lives of the nation's citizens. It is by the creation and diverse utilization of technology that, historically, we have measured the progress of civilization. It is primarily through the development and diffusion of technology that the flow of modern business and commerce takes place.

America does not have a formal and articulated policy for stimulating and guiding technology development. We do have numerous laws as well as many ingrained patterns and practices that govern the way that we envision, develop, and utilize technology. These guidelines and influences, viewed collectively, form an "ad hoc" national policy for technology. Given the questions about the performance of the United States as a competitor in the domestic and international marketplace, it seems timely to examine this "ad hoc" policy for its strengths and weaknesses; it seems necessary to ask whether a formal, articulated policy is needed to help us better compete in the changing and complex world economy, and it seems critical to identify the real problems and propose practical solutions. A visionary Congress should initiate dynamic public policy to insure the development and maintenance of national strategies for maximum utilization of our nation's knowledge and expertise in science and technology.

Implementation of the Agenda

The Task Force responded to these directions by studying the causes and effects of the trade deficit and the role of technology in rebalancing the deficit. Several industries in the manufacturing, service, and construction sectors were studied in an effort to understand the strengths and weaknesses which affect the economy. The automobile and electronics industries were chosen because of the market losses suffered in these areas. On the other hand, transportation, in general, was not studied because the problems in this area relate more closely to social encumbrances than to a lack of technology. Technology, as it relates to agriculture, was reviewed at a hearing on biotechnology. Since the United States is maintaining its strength in this area, no separate study was made. Declines in construction exports coupled with increasing imports prompted the Subcommittee on Science, Research and Technology to hold hearings which the Task Force used in its study of this industry.

This report emphasizes the importance of product development and manufacturing processes to the economy. It also emphasizes the need for more research and development in these areas in order to increase exports. This study is *not* directed toward the scientific end of the research and development spectrum. Science policy and basic research will be fully covered in a forthcoming report to be issued by the Committee. There is no intent to suggest that science or the funding of science and basic research are of any less importance than development and technology. The Technology Policy Task Force also recognizes clearly that science and technology are inseparable, that the scientist and the engineer must collaborate if the work of the scientist is to be transformed into products. On the other hand, the engineer must have a fundamental knowledge of the physics, chemistry, and behavior of materials related to his work in order to develop innovative products.

We have rapidly become the world's largest debtor nation; we are continuing to run trade deficits; our national debt is expected to reach $2.8 trillion in the next fiscal year; and worldwide industrial capacity far exceeds demand in a growing number of industries. Our current trade and debt problems will have to be resolved if we are to have a strong economy and a prosperous future.

As Robert Solow demonstrated in winning 1987's Nobel Prize in economics, technical innovation is central to economic growth. Because productivity in the United States is not advancing at the pace of our competitors then something is probably going wrong with the institutions and processes that determine the pace of technical change. It is unlikely that the pace of technical change can be increased without changes in the institutions and processes that control this pace.

The population has grown 60 percent, adding over 90 million people since 1950. This growth when coupled with dramatic expansion in communications capabilities and changes in social values have placed additional responsibilities on government. Government must change its methods of making decisions and responding to expanding responsibilities if it is to become effective.

We lack adequate long-range coordinated government policies directed toward future growth and prosperity. The structure of the U.S. Government was compared to other more centrally controlled governments at the beginning of the study. The question asked was: Can the U.S. compete economically against these centrally controlled governments in the international market? The Task Force found that we can compete, but that we will need to unite to do so. Traditional adverserial relationships that have existed between government and industry, labor and management, marketing and development, research and manufacturing, energy and environment, etc., must be replaced by relationships that foster cooperation.

Definition of Technology

There is no one single definiton of technology. Our Constitution mentions it using the term, "useful arts". Webster's New Collegiate Dictionary, 1975 states, "(1) technical language, (2) a: applied science, b: a technical method of achieving a practical purpose, (3) the totality of the means employed to provide objects necessary for human sustenance and comfort".

The terms "science and technology" and "research and development" are often used as if they each represented one entity. They do not. For the purpose of this report, technology will encompass the activities that generally *follow* scientific discoveries. *It will include* activities that lead to useful products. More frequently than not, these activities include applied research, conceptual engineering, preliminary engineering, prototype design, component manufacturing, prototype development and fabrication, testing and trials, redesign, quality assurance, and manufacturing.

Role of Technology in Stimulating the Economy

Technology development has played the key role in U.S. economic development. The economist, Edwin Mansfield, estimated that in the century following the Civil War technology advancement contributed to nearly 50% of the growth of the American economy. Denison estimated that for the period between 1950 and 1962, 34% of the growth in personal income in the U.S. was associated with advancements in knowledge.[1]

> If you don't have any technological or research capability, you may be at the mercy of those who produce the parts, and you may not even be in a position to accurately describe what it is you want them to do.[2]

Single Cause Phobia

It is the American character to argue that a problem has not been solved if one overriding cause has not been isolated. This search for the prime cause is perhaps the dominant reason why Americans have done so little to address the defects in the economy. Correcting each of many small causes is not part of the American style, but such small improvements are at the heart of large aggregate improvements.[3]

---

[1] Dension, Edward F., *Why Growth Rates Differ,* The Brookings Institution, Washington, D.C., 1967.

[2] *Mechanical Engineering,* December 1987, *GM's Healthy Pain* by Robert A. Frosch, Vice President, GM Corporation, p. 24.

[3] *Science,* Vol. 238, *A Weakness in Process Technology, Lester C. Thurow, December 18, 1987, p. 1659.*

Organization of Report

As listed in the Table of Contents, the report is divided into a summary, recommendations, and five sections:

Section A—appears *only* in the summary and outlines the economic problem that makes this report necessary.

Section B—covers the role governments, including Federal, state, and local, play in producing new technologies and how they disseminate technical knowledge to U.S. industry. This section also identifies various problems and suggests courses of action for making improvements in non-technical government policies.

Section C—explains how government policies both help and hinder the efforts of industry as it competes in the global market. Decisions made by government have tremendous influence over the behavior of private firms and thereby indirectly control the economy.

Section D—directs attention to the most important asset of any society—human capital—and examines how we can educate people to be more productive in a high technology society. A widespread lack of basic technical knowledge on the part of U.S. citizens inhibits technology growth. All citizens need a basic understanding of the technologies they employ and will be confronted with in the years ahead.

Section E—contains information on a few selected sectors of manufacturing, services, and construction industries. The Task Force relied on statistics and examples in order to include background information for the reader's consideration when addressing the problems and possible solutions that confront our industries.

Industrial Policy

The Task Force found that it would be counterproductive for government to tell industries how to run their operations. In fact, the policy recommendations in this study call for a greater inflow of advice from the private sector to the government in order to help establish federal programs. The Task Force believes that industry is better able than government to respond to the dynamics of consumer markets. However, government should cooperate and provide appropriate assistance to industry in helping it regain its competitiveness. One segment of U.S. industry, consumer electronics, has essentially been surrendered to the Japanese. Since it is a high technology industry and one that is still growing, government action is recommended. The Task Force realizes that government will continue to establish policies which affect business. Therefore, government policies and industrial practices must be in harmony if the United States is to have a strong economy.

SUMMARY

SECTION A—PREFACE—TECHNOLOGY AND THE ECONOMY

Economic Trends Since the 1960s

America's economic problems began in the 1960s when increases in productivity began to level off and U.S. industrial managers failed to make investments in new machinery. These shortcomings were compounded in the 1970s by the increase of new laws and regulations in response to heightened concerns about the environment, energy, and public health and safety. These concerns coincided with inflation, increases in the cost of labor and materials, and an enlightened public response. As new industrial nations gained strength, new products from abroad appeared on the U.S. market.

Many U.S. manufacturers found it more profitable to enter into arrangements with foreign companies than to compete. These arrangements also alleviated industry's need to invest in plant and capital for manufacturing and resulted in higher profits on investments. The combined effect of these forces was to seriously weaken the production capabilities of the U.S. Not only did our plants become relatively obsolete but workforce skills declined through the lessening of "on the job" training.

State of the Economy

Simply expressed, "America is in a deficit situation because it buys more than it produces[1] ". But a negative balance of payments is not an accurate definition of the problem. As Peter Peterson notes, dollars that flow abroad flow back to the U.S. to buy goods, services, or IOUs. In 1986 the U.S. sold $143 billion of IOUs to foreigners in the form of stocks, bonds, Treasury bills and other financial paper. Considerable foreign investments are also being made in real estate and other direct investments.

As long as we are unable to function without foreign investments, we can anticipate fluctuating exchange rates and rising interest rates which will be needed to attract more foreign investments.

Higher prices for imported goods are also bound to drive up the inflation rate in future years. While the fall in the

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[1] Peter G. Peterson, *The Atlantic Monthly*, October 1987, page 46.

> dollar's value makes U.S. products less expensive for foreign buyers, foreign goods in the U.S. also cost more and they now represent a major share of American consumption.[2]

In discussing the economy, Eugene H. Rotberg, Executive Vice President of Merrill Lynch & Co., related his concerns about the enormity of investments from outside the U.S. and the potential pressure this could put on interest rates and exchange rates. Mr. Rotberg said, "there is something structurally defective about a system that encourages borrowing for consumption rather than investment." He also went on to say that the basic external competitive issues are not sufficiently understood by Middle America. "Awareness is there, but acceptance is not."

Peter Peterson agrees, "America must learn the basic distinction between capital flows for investment, which produce future return, and capital flows for consumption-related debt (for example, inflows to fund the budget deficit), which simply produce future debt service." The solution, according to Peterson, lies in a national shift from consumption to saving with Americans producing more.

It is in the area of "producing more" that technology can be used.

> Strengthening the economy is essential because a failure to make corrections will result in a worsening economic situation as the debt service continues to build. A weak economy impacts everyone. In the first 8 months of 1987, prices outpaced wage increase by 2 percentage points.[3]

As tracked by the Department of Commerce, there have been dramatic shifts in the U.S. economy in the last 30 years. These shifts can be substantiated by reviewing the rise and fall of individual economic sectors. We have changed from a manufacturing society to a predominantly service oriented society. At the same time, we have seen the rapid growth of other industrial nations which now challenge our capabilities across a broad range of products and services.

COMPARISON OF ECONOMIC SECTORS

[Economic sector and year of maximum share of GNP]

The peak years for most product producing sectors was prior to 1985:

Apparel	1956
Farms	1956

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[2] Barry Bosworth, Economist, Brookings, Institution, *Washington Post*, Page C-1, October 25, 1987.

[3] Peter G. Peterson, *The Atlantic Monthly*, October 1987, page 46.

COMPARISON OF ECONOMIC SECTORS—Continued

[Economic sector and year of maximum share of GNP]

Passenger Transit	1956
Primary Metals	1956
Construction	1959
Petroleum and Coal	1962
Lumber/Wood Products	1965
Fabricated Metal Products	1969
Paper Products	1973
Motor Vehicles	1977
Textile Mill Production	1977
Air Transportation	1979
Chemical Products	1983
Electric/Electronic Equipment	1985
Machinery	1986
Rubber and Plastic Products	1986
In contrast, most services peaked since 1985:	
Federal Government	1956
Educational Services	1975
Health Services	1982
Real Estate	1982
Social Services	1982
Amusement Services	1985
Auto Repair	1986
Business Services	1986
Credit Agencies	1986
Holding Companies	1986
Insurance Carriers	1986
Legal Services	1986
Security Brokers	1986

The chart also indicates that some of the service sectors, by their nature, may be of less national importance than the product producing sectors. On the other hand, the service sectors have provided employment for 80 percent of the work force.

While the long-term economic outlook is clouded by the national debt, excessive foreign investment to finance debt, and the prospects of higher interest rates, the short-term outlook is bright. Unemployment is low, consumer spending is still strong, investments in plant and capital continue, and the GNP is still rising.

But from a macroeconomic point of view, the question arises as to whether the United States can continue to sustain a vast worldwide defense force, full employment, and at the same time pay off its debts, maintain multiple extraordinary national exploration programs, meet its entitlement commitments, and significantly reduce dependence on foreign capital and foreign oil.

The magnitude of the economic problems suggests that all of these goals cannot be attained. Instead, this report suggests that there is an urgent need to establish national goals on a more pragmatic basis; such goals will have to recognize technological realities and associated costs.

The Role of Technology in the Economy

What role can technology play in industry, manufacturing, and services which can lead toward a stronger economy?

The U.S. market is part of the global market. To compete, we can improve our productivity by taking advantage of new technologies in manufacturing processes. We should be able to increase our total output of goods and displace foreign-made products at home. We should also sell more products abroad. Technology can make it possible to produce more functional and better products that would have more sales appeal. We might, at the same time, decrease the work week to 4 days and still retain an acceptable level of employment if an across-the-board average 20 percent increase in productivity (manufacturing and services), could be achieved over time while holding wages to current levels.

But there is another element besides productivity. Many products which enter the U.S. sector of the global market do so because U.S. manufacturers choose to buy from abroad. They either have manufacturing facilities in other countries or agreements with foreign firms to distribute foreign products in the U.S. Frequently, U.S. firms will have components for their products made overseas.

Seldom will decisions to manufacture on U.S. soil be technology based. Decisions will most frequently be based on profit potential and risk avoidance. Why should a U.S. firm set up a new product manufacturing line? The stakes are high with all the inherent risks associated with the performance of unproven machinery and a work force with an insufficient number of highly-motivated people. When industry can sell a foreign-made product with more assurance of profit, there is less risk.

Does the United States have enough technology to compete? The answer is not clear.

The Development Process

Many hold the view that a scientific breakthrough is the key that leads to new products for the market, i.e., science initiates product development. On occasion, this so-called ladder process leads to the revolutionary development of a new product. However, for the most part new products are produced by steadily making cyclic, evolutionary improvements to existing products or to the processes by which they are manufactured.[4] In fact, in many instances when great breakthroughs in products have occurred, for example, the Wright Brothers' first airplane, the invention was empirically based. The principal utility of the science that followed was in cyclic product development and manufacturing. Science provides the logical structure that encourages and permits the continued evolution of improvements through cyclic development. If society considers science an end goal, rather than a means to an end, its quality of life and economic well-being will suffer.

During the middle 1800s, the U.S. began to build an industrial base largely fueled by the transfer of science and technology advances from the British Industrial Revolution.[5] From the early 1900s until after World War II, the U.S. depended on Europe, and Germany in particular, as a scientific resource and turned their discoveries into industrial products. Nuclear fission was discovered in Germany, yet the United States had the first applications as nuclear weapons, nuclear powered ships, and nuclear power plants.

This story has recently been repeated. Since 1950 Japan has turned in a superior performance of technology-based industrial development. The question asked by the Task Force was how can the U.S., unlike the British, counter the competition from Japan and regain our position as the world's leading economic power?

One thing is absolutely certain. By failing to participate in the development of new technologies and by relying on foreign firms to bring new products to market, the U.S. will lose its capabilities. To a large extent, the U.S. has already done this in consumer electronics and automobiles. According to the April 1988 issue of Consumer Reports, none of the cars made in the U.S. under American management compared favorably in terms of quality with automobiles made in Japan, or in the U.S. under Japanese management.

When we fail to produce our own products, U.S. management and labor both lose. In a very short period, the lack of experience leaves both groups behind because the development of any product, as well as the cyclic enhancement of existing products, is made possible only by knowledgeable people, our human resource. Knowledge of this kind does not come solely from reading books.

The academic community sees the solution to these economic problems depending an cooperation between industry, government, and universities. Such cooperation is one essential component for our recovery. The economic community sees the solution as one of shifting from consumption to savings, another essential component. But the business community is the one which can play a prominent role in restoring economic strength. As almost everyone knows, private firms are in business to make profits. Furthermore, as opposed to the Toyoda family which makes Toyota cars, or Mr. Sullivan Robert Dresser and his family who originated and built Dresser Industries, many U.S. firms today are captained by individuals who have no long-lasting personal stake in the longevity of the firm. Quarterly profits and dividends are the driving forces. The tenure of an average chief executive may be no more than 2 to 3 years. A merger is frequently found less risky than a new product line—especially if the CEO has little technical background.

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[4] Dr. Ralph E. Gomory, Senior Vice President for Science and Technology, IBM, "Turning Ideas Into Products", Spring 1988 Issue of *The Bridge*, National Academy of Engineering.

[5] Dr. Brook Hindle, Industrial Historian, former Dean of the University College and Head of the History Department, New York University, breakfast meeting, Technology Policy Task Force.

Technology Cannot Change These Conditions

A letter witten by Thomas Jefferson to Benjamine Austin in January 1816 provides guidance which is still appropriate.

> To be independent of the comforts of life we must fabricate them ourselves . . . manufacturers are now as necessary to our independence as to our comfort.

SECTION B—THE ROLE OF GOVERNMENTS IN TECHNOLOGY

Chapter 1—Government Technology Programs

Government funded technology can be put to more effective use in support of the economy when technology issues are elevated to the highest levels of government.

An organization is urgently needed within the Federal Government for the purpose of assuring that the U.S. remains at the forefront of technology. This organization could advise the President and Congress of the impact of major policy decisions on technology on a continuing basis. This organization would provide a united and sound technical basis for major decisions with the support of the Council of Economic Advisors, the National Academy of Engineering, and the Office of Technology Assessment.

Proposed organizational alternatives for fulfilling this responsibility include the following, among other possibilities:

1. Department of Science and Technology
2. Strengthening the Office of Science & Technology Policy
3. Council on Technology
4. National Policy and Technology Foundation

Regardless of the organizational structure selected, this body should include representatives from the private sector to provide guidance on prioritizing new advanced technology initiatives and technologies needed to support product development and manufacturing processes development.

There is an abundance of excellent engineers and technicians in the federal and national laboratories that can contribute to the development of technology for commercial applications. At their disposal are some of the finest equipment and facilities in the world. A major commitment of these resources to technologies which will help resolve national economic problems is in the best interest of the country.

Chapter 2—Technology Transfer

A large portion of the $62.3 billion spent on federal research and development programs is mission oriented and may or may not have commercial value. But a considerable portion of the research and development performed in government laboratories does potentially have commercial application. The rapid dissemination of the results of this research and development to the private sector is important to the economic security of the United States. The evolution of technologies forms the basis for new products and services. The private sector can benefit from the work accomplished by the government.

The most effective means of transferring this technology is through person-to-person contact. This requires greater mobility of both government and private sector personnel. But this mobility will result only from a desire on the part of all parties to work together on common problems. Industrial managers need to investigate the government resources available to them. These industrial managers should also inform the government about their needs so that government programs can be more accurately directed towards private sector requirements.

The government has programs in place which are intended to facilitate the transfer of technical data and knowledge to industry and universities. However, more effort is required to capitalize on them. The National Technical Information Service is one program which has been established to transfer technical data. It could be improved and expanded through cooperative arrangements with the Department of Defense, Department of State and other agencies.

The Task Force received a report from the General Accounting Office which identified certain barriers to technology transfer from federal and national laboratories. These barriers included: constraints in the transfer of computer software, in conducting proprietary research, in obtaining Department of Energy waiver of title to inventions, and in forming collaborative arrangements with industry. These constraints must be removed if the U.S. is to retain an up-to-date technology base throughout government and industry.

More autonomy for the selection of programs could be shifted from the departments and agencies in Washington to the laboratory directors in order to decentralize, eliminate bureaucratic delays and provide for improved government/industry relations throughout the country.

The government and the private sector could stay currently informed of current research and development work in other nations and incorporate the results of this work in their products and services. Private organizations could establish various means for obtaining this knowledge and the government could support this effort to a greater extent through its overseas agencies.

Chapter 3—Federal Budget, Process and Deficit

A nation which fails to use its resources to its best advantage can not expect to compete successfully in the growing international economy. The United States no longer has its domestic markets to itself. These markets are shared with other nations, several of which have well defined national goals for increasing global market shares, on a sector-by-sector basis. The U.S. therefore has to act in its own self-interest by maintaining effective national policies that make use of all of our resources for achieving our national goals.

Technology policies currently evolve through the budget process. This process, as currently practiced by the Federal Government, is democratic and offers the value-judgements that result from a democratic forum. However, the current budget process is complex with excessive duplication and overlap between Congressional Committees. Having to reauthorize each program every year creates instabilities with frequent redirection of research and development programs. As a result, programs become less effective. Multiyear authorizations, with a provision in the annual budgeting process that assures out-year appropriations, would also help.

The budget process allows for the initiation of projects and programs which might otherwise not be initiated if the selection were based on merit. This is counter to a process that first determines the necessity to perform a certain research task and then assigns a priority for authorization. As a result of the current process, some research does not lead to fruition.

A major problem with the budget process is that it is more attuned to the concerns of special interests, both in and outside the government, than it is dependent on the flow of information about the *results* of on-going technology programs.

It is important that funding of research and development be compared with other parts of the budget which do not provide for long-term improvements in the economy. The Task Force concluded that beginning with the FY 1990 budget, the Committee and Congress should look carefully at existing government programs in all areas and place the highest of priorities on the economic security of the nation.

The third largest item in the federal budget is $140 billion for servicing the national debt. The cumulative national debt is expected to reach $2.8 trillion in FY 1989. We are currently spending more on interest payments for the national debt than industry and government combined are spending on research and development. This debt-service results in a long-term outflow of capital and therefore affects the trade balance to the degree that a portion of the debt is owed to foreigners. While tax increases could reduce this debt, historically, tax increases have resulted in further spending increases that exceeded the new tax revenue by 50 percent. It becomes obvious that reductions in the national debt are needed. Funds for research and technology development, $64.6 billion for fiscal year 1989, constitute less than 6 percent of the budget and only 2 percent of the budget is dedicated to civilian research and technology development. The deficit problem can not be solved by reductions in this area. Furthermore, funds for research and technology development are investments in America's future.

Chapter 4—Defense

A strong defense is essential to assure continuation of the liberties of the American people, and it is the first priority of the Federal Government. Nevertheless, a strong defense is dependent on a strong economy.

Of the national investment in research and development (including investments made by the government and by private firms)—approximately $125 billion in 1987—the Federal Government provided about $62.3 billion. Of the government's total, almost 70 percent or approximately $42 billion was spent on defense. It is clear that defense research and development funds represent a major portion of government's investment in research and development. If our nation is to compete with Asian and European countries for international commercial markets and simultaneously compete with the Soviet Union in the defense arena, we must learn to make the most efficient use of our defense funds so that defense spending provides the maximum security for the dollars spent. Furthermore, we should improve our ability to make dual use (both commercial and defense) of those funds.

Several areas for efficiency improvements in defense work were recognized. Both defense and commercial industries benefit when defense research and development funding is invested in projects which serve as a catalyst to leverage industry investment in commercial products. Defense system designers could also avoid "overspecifying" military systems with contracts that contain unnecessary requirements and provisions. Defense contractors could emphasize efficiency and cost-effectiveness. When feasible, they could minimize costs through the use of Flexible Computer Integrated Manufacturing. Attainment of reliability through quality in manufacturing rather than after manufacturing through screening and testing can also reduce costs. The use of existing commercial technology can reduce production costs. The savings resulting from these cost reduction measures could be a source of additional research and development funds to promote industrial growth.

Excessively restrictive security classifications inhibit the transfer of defense technology to the commercial sector. National security export controls may unnecessarily restrict the international sale and export of U.S. made products.

Chapter 5—State and Local Governments

All elements of government, working together, can provide the conditions that are necessary to stimulate industry to manufacture products in the U.S. Cooperation is paramount to a strong economy.

Two areas that have excelled in developing high technology industry are Silicon Valley, CA, and Route 128, Boston, MA. Although both areas developed randomly without the guiding hand of government, the proximity of great educational institutions, Stanford and MIT, respectively, were critical to this growth. Defense spending was also an important impetus to this growth. In addition, close proximity of federal or national laboratories can aid in the growth of industry and, of course, the availability of capital is absolutely essential.

State and local governments can promote economic development by eliminating unnecessary policies, laws and regulations which prevent, restrict, or retard that development.

On the positive side, state and local governments can promote economic development by significantly improving the quality of their school systems, supporting universities, providing land and public works to encourage development, making better use of federal laboratories and facilities, providing appropriate tax credits, promoting capital formation, and establishing relationships with foreign countries to increase exports.

State governments have shorter lines of communication to private firms and universities than does the Federal Government. The Task Force believes that the real strength in our system of government, and in our ability to regain economic strength, lies at the state and local levels because cooperative arrangements can be made more quickly through person to person contact when people live and work in the same geographic region.

SECTION C—EFFECTS OF GOVERNMENT POLICIES ON TECHNOLOGY

Chapter 1—Government Policies in General

Government policies affect industrial development of technology in many ways; through taxes, deficits, Federal Reserve control of money supply and interest rates, information networks, legal and regulatory channels, etc. Instabilities in, and frequent changes of, government policies inhibit private business from making long-term capital investment in plant and equipment, new products, evolutionary improvements of existing products, and personnel training. For example, government policies on energy and the environment have been particularly inconsistent. Nuclear power had experienced strong support from government, then government became an adversary. Fluctuating government policies create an atmosphere of uncertainty that can contribute to industry's inclination to make largely short-term investments.

When making policies in response to conflicting pressures from special interest groups, rarely is government able to give consideration to the cumulative, overall affect of its policies or the long-term economic interests of the nation. Consequently, the nation's industrial competitiveness has been a minor issue in policy making. In all too many instances government policies designed to solve a problem in one area are in direct contradiction with the needs and policies of another area.

History offers us an opportunity to better understand the evolutionary nature of world economics. Assessment of 20th Century science, engineering, education, manufacturing, and economic practices in the U.S. show many similarities to those of 19th Century practices in Great Britain. Furthermore, comparison of government's role, financial practices, and industrial practices of the United States to those of export-oriented competitors show many differences. Generally these benefit the economies of our competitors, lead to undesirable consequences for the U.S., and promote growth of our trade deficit.

The time has arrived for the development of technical expertise in government that can span areas that are in frequent conflict—environment, energy, industrial growth, economic growth—and help government arrive at a consistent set of policies that meets the overall needs of our nation and at the same time gives our industries a consistent set of guidelines they can depend on for long range planning.

Chapter 2—Trade Balance

The dollar has declined in value but the trade deficit remains at a monthly level between $10 billion and $12 billion. The trade deficit was $170 billion in 1987. 1988 quarterly deficits are down about $5 billion from 1987 deficit levels.

The decrease in the value of the dollar will not by itself reduce the trade deficit to zero. Most believe that reduction or elimination of the budget deficit and much greater increases in rates of national productivity improvement are also required. To avoid a recession, decreases in the value of the dollar and reduction in the federal deficit must be accommodated slowly. Of course, reductions in the value of the dollar do not help in reducing trade deficits with those nations whose currency value is tied to the U.S. dollar.

The U.S. has become a high consumption, low savings country. Most economists agree that we should curb consumption and increase savings in order to balance trade and provide the domestic capital for investments to increase our productivity. We must produce more products and services for export, and for domestic consumption, and at the same time consume fewer imported services and products. To accomplish these goals, the U.S. private sector will have to make a national commitment to improve quality in products and services and to increase customer satisfaction.

The Technology Competitiveness Act contains many features which are intended to improve the ability of the U.S. to compete in the international market. An increased role for the National Bureau of Standards in supporting U.S. industry in technology development is called for in this Act. Increased cooperation between the national laboratories and industry is also promoted. These measures when combined with a tightening of the federal budget, an increase in individual savings, lower interest rates, and reduced consumption can begin to resolve the trade deficit.

Chapter 3—Long-Term Commitments By Industry

Most corporate investment decisions emphasize short-term returns because of high interest rates and long-term uncertainties in the business world. These uncertainties stem from many factors, including inconsistent and shifting government policies, changing savings rates, rapid changes in technology, growing productivity of developing countries, development of new materials, and shifts in the price of oil and raw materials.

The evolution of a "radically" new idea from its initial concept until a new product is ready for a competitive market can require between 10 and 20 years. Once a product is developed, evolutionary improvements can be introduced on a much shorter time scale, generally 2-5 years. Therefore, in many instances there is an incompatibility between the short-term needs of business and the long-term needs of technology. It appears that Japan has been able to sacrifice short-term profits in order to gain market share and achieve long-term profits.

Recent studies conclude that investment in capital promotes results in improvements in manufacturing equipment and increased research and development promotes innovation, and causes the rate of patent filing to increase. Economists are now generally attributing more importance to capital investment's role in economic growth than they did in the 1950s.

The cost of capital to industry is the factor that most controls the rate of capital investment. The rapid pace of technology development, fear of competitor imitation, lack of economy of scale, fear of technology rejection, and the short-term outlook of management all inhibit the investment of capital by our industries.

Policies that could encourage additional capital investment include: (1) government investments in technology research and development for selected industries and industrial cooperatives and the use of federal excise taxes on particular commodities in which investments are to be directed; (2) government purchases of advanced technology that has commercial potential; (3) government encouragement and support of cooperative research and development through modification of anti-trust and intellectual property law and regulations. Other measures to encourage capital investment include reform in accounting and financing systems and more government emphasis on research and development programs which also have commercial spin-off potential.

Chapter 4—Tax Incentives

Tax laws play an important role in promoting or discouraging technology development by industry. The allocation of capital and the willingness of the private sector to take risks are affected by tax law. While the Task Force received testimony for and against tax incentives, the prevailing opinion was in favor of tax incentives. As one industry said, "the more you spend on taxes, the less you have to invest." Those tax areas that have the most impact on technology development include research and development tax credits, capital gains tax, taxes on research and development limited partnerships, and taxes on manufactured goods.

Measures that the Federal Government can take to increase savings by individuals and reduce consumption are needed to promote the health of our economy. Increased taxes on consumption would help do this.

Although the tax policy of this country recently underwent major revision, little has been done to examine the ways in which the tax code stifles industrial development, including modernization of facilities and equipment, research and development investment, and personnel training.

Chapter 5—Patents

Our patent laws are intended to protect companies and individuals who are successful in inventing new products and manufacturing processes from those who would steal their work. It is the responsibility of government to assure that the patent rights of U.S. citizens are protected from infringement by foreign corporations as well as from other U.S. companies.

The role of patents in promoting inventions dates back to 300 B.C. Today there is little opposition to the need for patent law; everyone agrees that patent protection is essential for American industries. However, many deficiencies remain in our patent laws. Patent laws do cover manufacturing processes. Process patents do afford the inventor protection in the U.S. but, these laws do not stop a foreign firm from using the process in another country to make products which are then exported to the United States.

Although the Tariff Act of 1930 was intended to serve as a trade statute, the majority of cases that arise under it involve patent infringement by foreign firms.

In 1984, Congress passed the Patent Term Restoration Act and returned the years lost during pre-market regulation to the 17 year patent term for new pharmaceuticals, medical devices, and food additives. Although the government holds title to more than 28,000 inventions, ony 10 percent of these are used. The Bayh-Dole Act of 1980 gave universities, non-profit institutions and small businesses the option to retain title to inventions made using federal funds. A 1983 Executive Order extended these provisions to other businesses to the extent that the Order does not conflict with existing law. However, further changes in patent regulations in certain agencies are needed before these privileges can be extended to the rest of private industry.

SECTION D—HUMAN RESOURCES

Chapter 1—Technical Expertise

The United States retains a leadership position in basic research and technological innovation, but gives less priority than some of its trading partners to technology applications, product-quality, and marketing. It is not the quality of the basic research but the transition to product development that creates the problem. Weaknesses in American manufacturing have become more visible in recent years as foreign competition increases, although many American firms are taking steps to improve manufacturing and increase market access.

The Technology Policy Task Force concludes that in the long-term the greatest challenge to increasing sales in the global market lies in the education and training of our people. Particular emphasis is needed on the disciplines and trades that contribute directly to finished products such as manufactured products and construction projects.

The goal is to increase the proficiency of U.S. engineers and production workers so that the nation can be on the leading edge of technology, and basic research discoveries can be effectively converted into commercial products.

While recognizing the overall strengths of American engineering education, the Task Force supports recent recommendations for more emphasis on "the practice of engineering". Some of the problems in American industry can be attributed to corporate managers who may not have the technical expertise to make difficult choices among emerging technologies.

We do not function in isolation. International competitiveness depends on gaining access to foreign technologies and foreign markets. Technical expertise is essential. But our workforce also needs language skills and a far better understanding of the rest of the world.

The following is from a Task Force hearing on the effects of technological change:

> . . . there is an abysmal ignorance about the state of technology in the rest of the world, the degree to which in many areas foreigners have overtaken us. . . . what [can we] do to give our workforce a global perspective? What do we do to encourage people to travel? What do we do to encourage people to obtain language skills. . . . we have now the advantage of being in a sense number two in certain areas. We don't have to innovate totally. We can copy. We have learned that in our auto industry as the Japanese have moved in bringing with them their superior management techniques. But I think that exploiting this capacity to learn from others rather than to innovate and do it all alone is something that is going to be more open to us as, indeed, we become closer to a situation of first among equals, if you will, rather than this dominant technological giant.

Chapter 2—Mathematics and Science Education

Our ability to increase the proficiency of American engineers and production workers also depends on an adequate supply of well-educated high school graduates—the young people who will enter colleges and universities as well as industry.

International comparisons of mathematics and science achievement point out weaknesses in American education, although the extent of the problem tends to be overstated. While state and local governments have placed increased emphasis on mathematics and science education, additional reforms in these areas would better prepare students to continue their education in technical fields. The point is to improve course content rather than simply increase course requirements. The major problem is that the population in general is not well informed about basic scientific and technical issues or about how to apply mathematics to problem solving.

A fundamental revision of the U.S. school mathematics curriculum, beginning in the early grades of elementary school, is needed. This revision should include a more structured and comprehensive organization of the subject matter and a broadened curriculum including appropriate courses in geometry, probability theory, statistics, and algebra. Science programs should present a more focused discussion of a limited number of major scientific and technological concepts, with emphasis on practical applications.

The Task Force also urges a comprehensive instructional program in the International System of Units (SI): meters, kilograms, seconds, radians, joules, newtons, and pascals.

As more advanced artificial intelligence programs are developed, technology-based learning devices, such as computer interactive video disc technology and easy access to reference information stored on laser discs, can make an important contribution to mathematics and science education.

Chapter 3—Urban Education

The Task Force found that conditions in urban schools have reached crisis proportions. A large number of urban school children are not being properly educated. Our society can anticipate severe social problems in future years because a significant proportion of the population may lack the qualifications to participate in the work force.

Equally discouraging is that many who will be "left out" could have become high achievers. The entire society will lose. Nowhere will this problem be more acute than in America's high technology economic development which depends on the expertise of its engineers and production workers. And it represents a serious personal loss to these young people who will be relegated unnecessarily to low-paying jobs or to unemployment.

The problem is compounded by changes in the U.S. economy. Traditional manufacturing jobs that require less than a high school education have declined while jobs—particularly in information and high technology industries—which require more education have increased. Central city residents with higher education levels are able to take advantage of these new job oportunities, but those with less education often remain unemployed or find jobs only in low-paying occupations.

The Board of Trustees of the Carnegie Foundation recently concluded that improving the education of urban youth is the most critical issue the Foundation has addressed. But the Carnegie Foundation also mentioned that outstanding principals and teachers have turned failing schools around. For most inner-city students, however, the situation is grim. Failure to improve urban schools will have serious consequences for the ability of inner-city students to qualify for jobs and contribute to the nation's economic strength.

The Task Force concluded that a grants program inviting urban school districts to submit bids to establish pilot programs would provide a foundation for future advancements in urban education. Districts could propose programs in one or a combination of areas on a trial basis as follows:

- Small school units as recommended by the Carnegie Trustees. Small school size by itself does not increase student achievement. But, if managed well, small schools provide learning and motivational opportunities which are more difficult to achieve in less personal environments.
- Magnet schools which provide a general or specialized curriculum to students from across the school district. These schools typically attract additional resources but may have the disadvantage of reducing resources available to neighborhood schools. Like small schools, magnet schools provide increased learning opportunities. In some school districts, they also have attracted middle class students back into the public schools.
- College scholarship programs designed to increase achievement by offering financial assistance to qualified students. Current scholarship programs range from the city-wide programs supported by local industry and foundations to the widely publicized examples of classrooms "adopted" by wealthy sponsors who offer college scholarships as well as high school tutoring and other support services. Under a federal grants program, school districts might bring existing sources of support to students' attention, raise funds from local businesses and foundations, or use some of the grant money to provide direct scholarship assistance.
- Community support programs. Industry and university support has increased the effectiveness of schools in some inner cities

by offering both financial assistance and direct services—college scholarships, guaranteed employment to high school graduates, special university services to entering students, and services ranging from accounting to tutorial help in the public schools themselves.

- Plans to encourage principal and teacher accountability. Under these plans, individual principals and teachers are given more responsibility for education but also are accountable for results. Effective plans set realistic goals: The point is to measure student progress but schools are not expected to meet arbitrary test cutoff points.

Each of these programs requires resources which may not be available under many school districts' current budgets and constraints. A federal grants program with a strong evaluation component would give central city districts an opportunity to carry out and assess programs they consider potentially effective. These programs constitute one step in addressing a complex problem which goes well beyond the education system. But as part of a broader national focus on inner cities, they would provide information useful to other cities—as well as to states and the Federal Government—in setting future priorities for urban education.

Closely associated with problems in urban education is the recent decline in college enrollments of low-income students, particularly among blacks. As a result, many of these young people may not be gaining the education needed to compete for the growing number of jobs in information and high-technology industries. Black high-school graduates are increasingly going into the military or attending proprietary schools. Black male teenage unemployment is almost triple the unemployment rate for white males.

The fact that many minority youth come from low-income families living in high-crime areas and from poor schools is a major factor in the low college attendance rates. But another may be inadequate funds. Recent decreases in the "real value" of student financial aid and a shift in emphasis from grants to loans may have had unintended consequences for minority enrollment in higher education. Some minority youth may choose not to enroll at all. Others may choose lower-quality institutions to reduce the size of their loans.

One way of dealing directly with the financial problems of low-income students is to redirect federal aid for loans back to grants. Such a method could help provide incentives for elementary and high school students to excel in order to earn college tuition. In addition, witnesses before the Task Force made other proposals for financing education and training which circumvented traditional funding methods in an attempt to increase resources. One suggestion was for a federal loan program which would make it possible for anyone who wanted to undertake higher education or retraining in a recognized institution to receive full resources from the government and then be liable to pay it back through income taxes contingent on future income.

While the Task Force has not taken a position on specific alternatives, it urges that priority be given to public policies which facilitate the access of low-income students to higher education.

Chapter 4—Continuing Education and Transitional Programs

The Task Force recognizes that changes in the global market have caused many American workers to lose their jobs in traditional manufacturing industries. A number of factors contributed to these job losses:

- decreased product sales induced initially by the high value of the dollar which once lost are difficult to reestablish;
- increased competition from other countries;
- the world debt crisis which has resulted in a loss of markets in debtor countries;
- oversupply of certain commodities;
- substitution of products;
- shifting consumer preferences.

Some of these job losses also resulted from the development of new technologies which led to increased productivity in the manufacturing sector. Indeed, technological advances are a mixed blessing. While they have a positive impact on employment and wages for the economy as a whole they often cause hardships for workers in specific industries.

Many of the workers who lost their jobs have been absorbed in the job market, but at lower wages. Others have remained unemployed for a variety of reasons: inadequate training or education, lack of labor mobility, age, etc. The report discusses several proposals for accommodating employee dislocations: (1) continuing education; (2) declining tariffs to finance worker readjustment programs; (3) basic skills programs; (4) reemployment programs; (5) strengthening Title III of the Federal Job Training Partnership Act (JTPA); and (6) early retirement options. Many of the proposals are intended to provide alternatives to special protection by easing the transition through difficult periods. While the Task Force has not taken a position on specific proposals, it emphasizes the importance of public policies for alleviating adverse effects of industrial transition on workers.

SECTION E—INDUSTRIAL SECTORS

Chapter 1—Manufacturing

Manufacturing employs approximately 20 million Americans and provides jobs for another 40 million in the service sector. The total value of goods manufactured in the U.S. in 1987 was $2,408 billion.

During World War II, U.S. industry was at full capacity, building war materials to support the Allies. After the war the U.S. was the world's industrial leader, in part because potential competitors either had their industries destroyed during the war or were burdened with such great war debts that capital investment in manufacturing was restricted.

After the war, the productivity growth rates of Europe's and Japan's industries grew rapidly, in part, because they started so low on the productivity ladder. Between 1981 and 1986 the U.S. went from a positive trade balance position of $6 billion to a deficit position of $141 billion. Of the total swing of $147 billion, $135 billion was due to an increase in imports of manufactured goods. By 1984, imports exceeded exports in electronics, the world's largest manufacturing business with 1987 sales of $550 billion. By 1987 electronics imports exceeded exports by almost $13 billion. The U.S. consumer electronics industry, an industry born in the U.S. and an industry with worldwide annual sales in excess of $75 billion, had practically vanished, with U.S. built products providing less than 5 percent of world sales. The future of consumer electronics is closely tied to the success of high definition television, an area in which U.S. research and development lags Japan.

When we look at the basic building block of electronics, semiconductor technology, we find that by 1986 Japan had a larger fraction of the international market than U.S. based firms. Except for computer-aided-design of integrated circuits, Japan is technologically superior to the U.S. in every area. Of most concern is Japan's superiority in integrated circuit manufacturing because this capability will further widen the gap between U.S. and Japan in the associated technologies.

There are many causes for erosion of the U.S. position in manufacturing:

1. underemphasis on manufacturing process development;
2. underemphasis on quality—especially achievement of quality through simplicity of design and processing as well as designing for ease of manufacturing;
3. slowness in moving through the development cycle to make evolutionary improvements in products;
4. underemphasis on making effective use of integrated manufacturing systems;

5. and, in general, under-investment in research and development and new plant facilities that promote improved productivity.

The Task Force concluded that U.S. industry needs to form a consensus on the vital importance of quality and productivity improvement and establish long-term goals that can provide for a stronger economy. Industry then needs to inform government of the goals through an advisory structure and assist government in determining how it can help attain these goals. Government needs to establish a group or groups of highly qualified analysts who study industrial problems in cooperation with industrial trade organizations and other industry groups and advise Congress and the President on actions needed to support America's manufacturing industry.

The survival of the U.S. consumer electronics industry requires that government take immediate steps to assist in preserving this important industry. One alternative for consideration is the establishment of a consortium in consumer electronics manufacturing research and development partially funded by government.

Chapter 2—Services

Approximately 80 percent of the American workforce, over 90 million people, are employed in service industries. Clearly the United States economy has shifted from manufacturing to services.

The United States currently has a high level of employment compared to most other industrialized nations. There have been early indications that the service sector is no more vulnerable to a recession than is the manufacturing sector. On the other hand, the service sector may not be a safeguard against a weak economy. Approximately 30 million people, more than all the people employed in manufacturing, work in retail shops and eating establishments. Many of these jobs are part-time or part-year. A significant number provide services in the luxury category which could realize sudden declines as family disposable income shrinks.

New technologies have contributed to the expansion of services by providing the capability to perform new services and by accelerating the growth of existing services. Telecommunications, information systems, and banking are especially technology-intensive and will continue to undergo major changes. For example, by the 1990s, increased integration of telecommunications, with data sources, commercial banking, investment firms, retail distribution centers, educational institutions, and other services will enable people to conduct many actitivities from home information centers.

The shift from manufacturing to services has been a long-term trend in industrialized nations. At least in part, this transition stems from increased productivity in the manufacturing sector. But it is important to distinguish between shifts to service industries resulting from rising productivity and those which stem from abandoning production to others.

Trade in services is small compared to trade in goods but it is of considerable importance internationally. The Office of Technology Assessment estimates that services account for about one-fourth of American exports—higher than the 17 percent indicated in official government statistics. While the United States runs a positive trade balance in almost all services in which all regions of the world participate, there are competitive threats comparable to those we have seen in manufacturing. The collection and analyses of more accurate data pertaining to service industries is needed to help inform government policy-makers about trade in the service sector.

The productivity of American service industries can be expected to affect our balance of trade. While manufacturing productivity has increased, some analysts conclude that productivity in the service sector is down. This decrease is contrary to conventional wisdom, which assumes greater productivity, and fewer jobs, with increasing computerization. Indeed, just the opposite may have occurred. Service industries have provided a growing number of jobs, in part because they are inefficient.

Chapter 3—Construction

At one time the U.S. construction industry was a dominant force in construction projects throughout the world. This dominance was largely a result of the superiority of our construction technology. Despite the fact that in 1986 the U.S. construction industry had sales of $375 billion, data show a 20-year downward trend in productivity. U.S. construction industry's share of GNP has decreased over this period and the amount of U.S. construction work done abroad has decreased. Meanwhile, foreign interests have been acquiring U.S. design and construction firms and the number of U.S. construction jobs going to foreign firms has increased.

Because of the small investment in construction research and development (only 0.39 percent of total sales), the technological superiority of the U.S. construction industry has been gradually eroded. The disinterest in research and development investment by this industry is most likely due to the small, splintered nature of construction firms. Japan, on the other hand, has extensive research and development facilities in support of its construction industry. For example, prefabricated, low-cost housing featuring new, long-life materials is growing rapidly in Japan as is computer-aided design of structures. The U.S. construction industry has placed more emphasis on human inspection of construction projects than designing-in quality in the first place. This may have been partially the result of increases in federal and state regulations.

Consideration could be given to establishing a joint industry-government consortium to conduct research and development on behalf of the U.S. construction industry. Membership could include: (1) construction industry representatives including those who manufacture products used in construction; (2) the Corps of Engineers; (3) the National Bureau of Standards; and (4) the Federal Highway Administration. Hearings to determine the level of industry interest in such a consortium and the willingness of industry to share funding with the U.S. Government could be conducted.

The severity and economic impact of foreign-made counterfeit construction products that are being illegally brought to the U.S. could be further investigated to determine appropriate action by Congress.

RECOMMENDATIONS

1. Less than six percent of the federal budget is spent on research and development. However, this part of the federal budget when combined with about the same level of investment from industry, fuels our economic future. Therefore, it is imperative that we make effective use of research and development sponsored by government. To improve the way research and development allocations are made by the government, it is necessary for technology issues to gain greater visibility at the highest levels of government.

The United States needs an organizational body with the credentials and the position to influence both the Executive and the Legislative Branches of the government and to initiate policies which would then define program priorities for inclusion in federal research and development budgets.

The decisions made by this body would define programs for the purpose of enhancing the position of the United States in world trade. These decisions would be improved by devoting greater resources to collecting and evaluating data received from sources throughout the world.

The Task Force, therefore, recommends that the Committee on Science, Space, and Technology further investigate opportunities to enhance the development of technological products and manufacturing processes by:

> A. Determining the kind of organization that might have sufficient influence to be respected and followed by Executive departments, agencies, and OMB, and endorsed by Congress through authorization bills when setting national priorities for research and technology development.
>
> B. Drafting the legislative language which would consider the size, composition, and structure of such an organization, the required facilities, the method of funding, how it would be administered, and of most importance, how it would interact with industry and accept and make use of industrial guidance.

In this regard, the Task Force notes that there are at least the following choices: (1) A Department of Science and Technology; (2) A change in the enabling language to expand the Charter for the Office of Science and Technology Policy; (3) A Council on Technology composed of representatives from industry and government; and (4) A National Policy and Technology Foundation.

2. The Task Force strongly urges a significantly expanded role for the federal and national laboratories. As a first step, the Task Force recommends that the Committee on Science, Space, and Technology investigate the current charter of each national laboratory and NASA center and determine those disciplines, technical development experience, and other attributes which would qualify them for supporting a particular or several industrial areas such as:

aeronautics;
computer systems;
electronics products;
steel and aluminum processing;
materials development;
environmental equipment;
mass transit systems;
manufacturing processes;
construction;
office systems;
television systems; and
semiconductor technology.

The legislation should provide for major programs directed toward increasing the quality and reducing the cost of U.S. products in order to obtain a competitive advantage in the U.S. domestic market and in foreign markets.

To fulfill this purpose, the legislation should grant significantly more authority to laboratory directors as well as immunity from Executive agency micromanagement. The selection of programs by laboratory directors should be made in concert with industry on the basis of industrial (manufacturing and services) requirements as well as industry's ability to cost-share. While final approval would be retained at department and agency levels, program selection should primarily rest with laboratory directors.

3. As part of extending federal resources for the development of commercially oriented technologies, the Task Force recommends that the Committee on Science, Space, and Technology explore the potential for authorizing civilian-oriented research and development programs to the Corps of Engineers for the specific purpose of supporting the construction industry. This recommendation is made because of the market penetration by foreign construction firms and because of the shortfall in construction research and development. The Corps of Engineers has a history of experience in the development of construction equipment and in developing construction methods.

4. During the course of the study, as described in Section D, Human Resources, the Task Force found that conditions in urban schools had reached crisis proportions. A large number of urban school children are not being properly educated. As a result, a significant proportion of the population may lack the qualifications to fill a productive role in occupations which require technical knowledge. This is in contrast to 50 years ago when urban schools produced many of our best scientists and engineers.

Therefore, the Task Force recommends that the Committee on Education and Labor and the Committee on Science, Space, and Technology consider legislation for "pilot" programs in various urban areas. These programs could evaluate the most effective means for improving achievement levels in these areas. The programs could be based on grants made in response to proposals submitted by urban school districts. They should include:

- small school units
- magnet schools
- college scholarship programs
- community support programs
- plans to encourage teacher and principal accountability.

5. The United States has almost totally lost its consumer electronics product manufacturing capability. With the coming of high definition television (HDTV), the U.S. will be inundated with foreign products with a further set back in trade balance. Our lead in personal computer manufacturing will be at risk. The Task Force, therefore, recommends that the Committee on Science, Space, and Technology consider legislation for the purpose of restoring the U.S. consumer electronics manufacturing industry. Government funding for preserving this industry could come from a federal excise tax on consumer electronics and would be justified on the basis that most consumer electronics items are in the luxury category. When Japan's consumer electronics industry required assistance, its recovery was aided by a 30 percent excise tax.

These funds should be used to initiate a National Electronics Manufacturing Center in a geographic area which already has a history in developing and manufacturing electronics equipment. There should also be a university in the area as well as experience in electronic defense systems.

6. The Task Force identified many weaknesses in U.S. manufacturing practices. Many of these stem from inadequate management and engineering in production plants. These shortcomings are the result of a lack of support for manufacturing operations on the part of a large number of corporate executives. Many executives are business school graduates who may not have the technical expertise to make difficult choices among emerging technologies. As a result, managers often look abroad for production as an easier path to profits. Manufacturing managers and engineers are generally

paid considerably less than their associates in other divisions of corporate America. However, it is in manufacturing where quality and product cost become of paramount importance to corporate profits.

Since many corporations are reluctant to respond to a national need for domestic manufacturing, the Task Force recommends that a college institute or university be selected to become the national leader in manufacturing technology. The Task Force recognizes that many universities offer excellent courses in manufacturing. But, manufacturing occupies a "second class" position among the university elite. Furthermore, there has not been a national recognition of the importance of these disciplines to national economic strength.

The Task Force recommends that the Committee on Science, Space, and Technology consider legislation for designating an existing college, institute, or university to host a National Institute of Manufacturing Engineering and Management. This Institute should be founded on the land grant tradition with initial government funding authorized to the National Science Foundation for this purpose.

TECHNOLOGY POLICY REPORT

SECTION B—THE ROLE OF GOVERNMENTS IN TECHNOLOGY

CHAPTER 1—GOVERNMENT TECHNOLOGY PROGRAMS

ISSUES

1. To successfully compete in the international market, the United States Government could make more extensive use of its research and development institutions in areas of product development.
2. The Federal Government needs a vastly improved method for selecting research and development programs in place of relying on the budget process for this purpose.
3. More emphasis could be placed on development work which is needed by U.S. industry to compete in the global market.
4. The national and federal laboratories lack the freedom needed to enable them to respond quickly to the dynamics of global economic changes.

DISCUSSION

After decades of dominance as the world's leading industrial power, America's leadership has eroded. Japan, Western Europe, and a host of other countries have made rapid gains in industrial strength. As George C. Lodge explained to the Subcommittee on Science, Research and Technology:

> The erosion is occurring not only in mature industries, such as steel and automobiles, but also in those of the future upon which our nation's standard of living over the long run depends: machine tools, robots, fiber optics, telecommunications, semiconductors, civilian aviation, electronics, pharmaceuticals, and even in service industries such as banking and finance.[1]

The United States has long maintained superior scientific research, proven by its dominance in Nobel Prizes. Where the United

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[1] Statement of George C. Lodge on *United States Competitiveness in the World Economy*, before the House Subcommittee on Science, Research and Technology, June 26, 1986.

States has had difficulty is in the transfer of that research excellence into economic competitiveness. It is clear that other governments give great support to their industries in order to ease and speed commercialization of new products and processes.

The Fiscal Year 1989 budget contains $64.6 billion for research and development. Although this amount represents only 5% of the total federal budget of $1,232 billion, it is one of the most significant parts in terms of potential return on investment. Private corporations invest in research and development in order to remain competitive and insure future earnings. On a national basis, the government makes research and development investments in two general groups, defense and those areas where it is impractical for private corporations to make large investments on their own, such as in the Space Program.

In a world where technology advances from minute to minute in universities, laboratories, design rooms, test facilities, and factories in locations such as Seoul, Yulich, Kiev, Princeton, and Kobe, there are basically two choices. The United States can either maintain a level of investment which will support advancements in products and services or it can fall behind and therefore depend on other nations for its new products and for improvements in existing products.

An industry survey made by the Task Force suggested that more federal research and development funding could be concentrated on generic technologies which could provide a foundation for future commercial products. The high cost of capital has directed corporate research and development funds away from long-term product and process development. In addition, the benefits of basic research have not been transformed into commercially competitive process technology and manufacturing as it should be. For example, when government policies produce an economic environment which is not conducive to producing products at home, U.S. corporations produce them abroad or purchase them from abroad for resale in the U.S.

However, the number and cost of research and development programs in the Federal Government has reached a level where adequate funding for all programs and projects is in serious jeopardy. The Space Station and the Superconducting Super Collider are examples. Many programs are already underfunded at a time when the budget deficit could force further reductions. As a result from this point forward the Administration and Congress should improve their procedures to establish priorities if the most value for the investment is to be obtained. These priorities should logically be based on *potential usefulness* to the nation and on *technical* *merit.* The present methods used in selecting research and development programs fail miserably in making choices.

The absence of technical knowledge at the upper levels of government is also a matter of grave concern. From all indications, many multi-billion dollar decisions involving highly technical programs are made on a nontechnical basis or founded on the comments of trusted friends rather than after meticulously collecting all the pertinent information and making a careful analysis.

A National Policy on Technology

There is a new global reality.

> We are being beaten by nations which have a more competitive national strategy, one that is aimed at earning a higher standard of living by gaining and retaining competitiveness in the most profitable and fastest growing industries through investment in those industries, looking for long-run market share, not short-run profits, with government acting as coach if not quarterback, building and maintaining a consensus among various social groups that ascribes a high priority to competitiveness.[2]

The United States Government currently lacks an adequate mechanism for determining which research and development programs should have national priority. This is one reason the U.S. is not as strong as it should be in competing in the global market. Our process for choosing development priorities which could support industrial growth is inadequate.

Dr. Karl Willenbrock identified the need for a long-term federal commitment:

> Major changes in public policy, particularly on short time scales, are disruptive to the intellectual, financial, and institutional commitments which are essential to continued technological progress. While there may be substantial disagreements on how best to deliver health care services to the American public, there is no question that the Federal Government and its National Institutes of Health are committed to improving the health of the public and will continue to support medical research.
>
> Many technological developments require a greater time and facilities commitment than industrial managers are able to make. In such cases, it may be necessary for a federal agency to support development of a technololgy for an

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[2] Scott, Bruce R., *Competitiveness in the World Economy*, Harvard Business School Press, Boston, Mass., 1984, Chapters 2, 3.

> extended period of time, up to the point that the private sector can take over and move into the commercial development phase . . . .[3]

In a letter to Chairman MacKay, Dr. Robert M. Price commented:

> . . . It is not enough to generously fund basic research and hope that American industry will reap the benefits. It is also nearly impossible today to find a high-tech industry that does not involve high risk expensive development . . . .
>
> . . . The major weakness in the innovation process from invention to product in the U.S. lies in development—the activity that connects basic research with production . . . .
>
> . . . Japan's success in harnessing research and development is due to an orchestrated division of activities and responsibilities with government acting as the catalyst and industry taking a lead role as a funder and performer of research and development. West Germany also has a complete research and development system covering all aspects of the innovation process. In particular, its Fraunhafer Society for Applied Research (FhG) is the government's central applied research and development organization with the primary responsibility to develop technologies and to foster their diffusion to industry, especially small businesses. The FhG comprises 34 separate institutes each having a commercial orientation. Although two-thirds of the costs are covered by direct industrial contracts with the balance handled by the government, industrial sponsors can obtain government assistance in financing their share of the costs . . . .[4]

Early in the course of the study there were discussions about the Japanese Ministry of International Trade and Industry (MITI). There was agreement that MITI had served its government well in supporting Japan's rapid industrial growth and success. But, there was recognition that the United States Government could not embark on a course of industrial policy and that "central planning" was counter to our government structure. On the other hand, many of the functions that MITI performs are not adverse to our prevailing concepts of government-industry relations. In fact, many of those functions are essential to competing in the world market with products dependent on technological advancements.

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[3] F. Karl Willenbrock, Executive Director, American Society for Engineering Education, letter to Chairman Buddy MacKay, September 22, 1987.

[4] Dr. Robert M. Price, Chief Technical Officer, Vice President, Research and Engineering, Control Data, letter to Chairman Buddy MacKay, September 4, 1987.

MITI's mission is to promote the development of Japanese industry, and its Agency for Industrial Science and Technology (AIST) helps achieve the mission by promoting science and technology. Each year MITI hires about 25 university graduates who will become elite bureaucrats and about 25 who will become science and technology officials. In the past these science and technology officials, assisted by almost 500 AIST employees, *guided the efforts to scan the world for scientific advances with commercial potential.* Japanese efforts to catch up in science and technology are not totally unlike those in America from 1880 to 1940 when America was behind in many areas of science and our scientists studied French and German to follow worldwide scientific progress, especially in England, Germany and France. *However, with the great expansion of science and technology in recent years, current Japanese efforts are much larger, more centrally coordinated, and they are also more focused on commercial application.*

Once MITI, in collaboration with the private sector, identifies promising areas to be further investigated, much of the initiative can be left to others. *Private businesses organize study teams to explore the new areas. Even newspapers and technical publications, aware that their readers want to follow developments in these areas, send their own people to cover the stories.* Students flock to these promising areas for they consider it a great opportunity for their own career. Funding agencies, knowing the priorities, give grants in these areas. Companies vie to establish research programs to capture the leading edge. The most advanced students who go to the best centers in the world choose these areas in which to study. Thus MITI's role is not so much in subsidizing these areas as in working with specialists to help identify key areas.

Other organizations respond readily once the areas are identified, and if new areas are identified, people respond quickly.

AIST has some 16 labs, some regional, to help bring the latest ideas to the major regions of Japan, but mostly specialty labs, to supervise the following of technologies that might be important in the future. Originally the forerunner of AIST had responsibilities similar to our Bureau of Standards. The role was not only to introduce international standards but also to raise quality standards, as Japanese industry improved its capacities.

As Japan began to catch up in technology, AIST could turn its efforts to guiding new research and development in areas like semiconductors, computers, energy conservation, alternate energy sources, new materials, optics, and lasers. Japanese companies, like those in other countries, are not eager to share commercial technology with their competitors. The job of the AIST project officer putting together joint research projects is to know companies well enough to know how far companies can work together in basic research and development in areas slightly removed from immediate commercial products. The project officer must also bargain with the companies to arrive at a financial estimate of the minimum amount of funds the government must put in to get the cooperation of the participating companies. He must often make some special concessions to get the company with the leading technology, and therefore, most tempted to try to go it alone, to join in the project. He must also bargain with the companies to send quality personnel to carry on the joint projects.

AIST defines its role as supplementing market forces. *It therefore takes risks in new developments that companies consider too great. It undertakes projects that are considered too far from commercial application or too expensive.* When several alternate technologies or scientific developments are possible, AIST can put together several consortia to ensure that companies do not pursue only the most promising technologies. It must, in this case, find ways to assure those companies asked to pursue the less promising technologies will share in the discoveries made by research in the more promising technologies. It also tries to ensure continuity in research projects despite fluctuations in the market. *When the price of oil went down, U.S. research in alternative energy sources went down precipitously, but AIST ensured that in Japan these research projects would continue uninterrupted since they wanted to be prepared for contingencies in case the price of oil would rise again.*

The trust of Japanese research and development has grown from copying to creating and from projects where results were expected soon to those where results were remote and risky. Still, compared to the U.S., *Japanese research and development has a higher component of development and is motivated more exclusively by commercial ends.* Around 1970 when major Japanese firms first began

> building central research labs, the central labs became in effect product development labs for products likely to be developed 5 to 10 years in the future. Commercial goals remain preeminent, but as the scale and time horizon of research expands, the distinction between applied and basic becomes harder to make.[5]

Pragmatic Approaches to Development Program Selection

For many reasons, including restricted federal budgets, research and development work should proceed only after careful consideration of all the technical information available. Actions by the government should be based on more than a quick response to an event. The following example illustrates the point.

In January, 1986, Karl Alex Muller and Johannes Georg Bednorz discovered a ceramic material which exhibited superconducting properties at 35°K (−238°C). About a year later research teams headed by Paul C.W. Chu at the University of Houston and Maw-Kuen Wu at the University of Alabama discovered a different copper oxide which exhibited superconducting properties at 94°K. This higher temperature would reduce the cooling cost which is important to the practical use of these materials.

These discoveries prompted considerable interest in government circles in many countries. In the U.S., the Department of Energy doubled its superconductivity research in 1987 to $40 million and the Department of Defense developed a three-year $150 million research-funding plan.

While higher temperature superconducting materials offer many opportunities for new products, rapid funding increases may not have been the best way to proceed.

According to Dr. Rustum Roy, a federal policy should be carefully constructed.

> . . . there was a major discovery in materials research, partly by chance, in Switzerland. Today literally hundreds of labs are working away in private industry, universities and government labs all over the world following up on this discovery.
>
> Promising results are emerging without any crash programs anywhere. Should a government committed to free enterprise for industrialization do anything at all when industry is already so active? And if so, what?

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[5] *Research and Development in FY 1988: Research and Development Policies, Budgets, and Economic Competitiveness,* Colloquium Proceedings 9 and 10 April 1987, Edited by Susan L. Sauer, American Association for the Advancement of Science, pp. 65–67.

> First, the United States is hardly the only or major player in this game. Switzerland, Japan, India and China have at least equal claims to major contributions. Indeed, the basic scientific strengths in materials chemistry on which these materials were based are to be found in France and the Soviet Union.
>
> The United States is particularly weak in this field. Most of the U.S. work was by physicists doing amateur chemistry. Neither does the work abroad have the frenetic quality we have.
>
> Second, to link these developments directly to potential improvements in U.S. competitiveness is inexcusable exaggeration.
>
> The state of U.S technological industry is what needs fixing, and simply giving more money to U.S. universities for superconductor research will make things worse, not better.
>
> The scientists of other countries are not interested in generating new science: i.e., being No. 1 in publishing papers. They are perfectly content to be No. 1 in utilizing science from the worldwide production thereof.
>
> Perhaps we need three or four modest integrated or networked (as we at Penn State call them) research and development collaborative efforts bringing together the scarce talent in the field into two or three teams of industry, university and government labs.[6]

The results of the Task Force's industry questionnaire, indicated a need for federal laboratory support. The private firms questioned felt that there was an urgent need for government laboratories to seek advice from industry for their research activities in an effort to derive greater commercial benefit and to streamline technology transfer. The use of advisory panels in the development and evaluation of government laboratory research agenda was strongly recommend.

U.S. Industry to Define Federal Research and Development Programs for Industrial Support

Thomas J. Murrin, formerly President of Energy and Advanced Technology, Westinghouse Electric Corporation, believes industry should play a major role in establishing U.S. technology policy.

> . . . Industry should play a major role in coordinating with government the relative priority of the funding allocations.

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[6] Associated Press, Dr. Rustum Roy, *The Patriot*, August 17, 1988.

> This would help to ensure that the technologies that best serve the marketplace receive top priority. . . .[7]

For the United States, there needs to be an alternative to the haphazard approach to technology policy. An organization of some type is needed. This organization must have sufficient influence to set a policy for engineering and development within the Federal Government. It must develop programs which support industrial progress. It should directly include private industry in the decision making. It should also include universities and various government entities.

Fred Garry, Vice President of G.E. informed the Task Force:

> . . . With regard to federal laboratories, it seems to me that the use of a three-party (government, academe, industry) advisory board (similar to the pre-NASA, NACA concept) could establish priorities and schedules that would make these endeavors more market oriented. . . .[8]

The major problem is that no organization at present has sufficient political influence to establish policy on a realistic basis. The departments, agencies, Office of Management and Budget, Congressional authorizing committees, and Congressional appropriations committees all vie each year for pieces of the budget pie. The outcome of this competition is, in fact, a short-term technology policy, altered the following year by new budget debates. Realistic policies will have to be based on a strong technical knowledge and deep understanding of the potential and limitations of various technologies if the U.S. is to regain a larger share of the market.

What is needed is a way to carefully select technology programs on a priority basis. If this is not done, all programs will be compromised including the essential ones. If budget cuts are made on a prorated basis, the probability of success on most programs will decline and, in turn, the quality of the work will decline. The results may foreclose what otherwise could have been history-making successes.

In testimony before the Technology Policy Task Force, Dr. Lew Branscomb said:

> Here we have a government which is spending some $67 billion a year in research and development and is leveraging the other $70 billion of private research and development through the government's regulatory actions and behavior in the marketplace. Yet, for the last two Adminis-

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[7] Thomas J. Murrin, President, Energy and Advanced Technology Group, Westinghouse Electric Corporation, letter to Chairman Buddy MacKay, September 29, 1987.

[8] Fred W. Garry, G.E., letter to Chairman MacKay, September 25, 1987.

> trations, both of the last two Presidents, that is Mr. Reagan and Mr. Carter, didn't get around to appointing a Science Advisor and director of OSTP until the middle of the Spring. This was after every other senior job had been picked, after the White House staff was completely locked up. Hence, there was no bargaining power available for the candidate to negotiate with the Chief of Staff or with the President about what his relationships might be with White House Offices, with OMB and with the Cabinet Offices. The Assistant Secretaries for research and development were chosen before the Science Advisor could have a possible voice in their selection. Had he had a voice in their selection, be might have had more responsive behavior on their part.[9]

After considering the comments from the Advisory Board, the Task Force attempted to determine how policy decisions could be made on a more pragmatic basis. The history of some past organizations was reviewed and the records from a hearing held by the Subcommittee on Science, Research and Technology on the Office of Science and Technology Policy were reviewed.

The following alternatives are presented for organizations that have the potential to be respected by the Executive and Legislative Branches of the Government as well as by private industry.

The Office of Science and Technology Policy (OSTP)

The Office of Science and Technology Policy was formed in 1976 for the precise purpose of assuring that decisions involving technical matters were based, at least in part, on such things as the laws of physics and practical engineering.

One of the advantages of OSTP is that it is geographically located near the Executive Offices and the Director is the President's Science Advisor. As the Science Advisor, this person should have access to the White house staff and play an important role in key decisions at the highest levels of government.

The organization is staffed with highly qualified people who have access to an abundance of information. OSTP also has maintained contact with individuals in the private sector through committees that review and report on technical issues. The principal advantage of OSTP is that it already exists and as such would not take years to become effective. It would not become an additional cost burden as would a completely new organization.

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[9] Technology Policy Task Force of the Committee on Science, Space, and Technology *Hearing on Communications and Computers in the 21st Century*, June 25, 1987, p. 63.

In spite of OSTP's existence, we continue to inhibit our own national competitive position by slighting technology, except for defense purposes, at the highest levels. Our government has wasted precious time and money on daring ventures that floundered because they were technically ill-founded. In other parts of the world, industrial competitor nations are making rational decisions based on appropriate knowledge. This is not happening in the U.S. government because each department and agency is autonomous with no one in the Executive Branch having overall coordinating authority. The President's Science Advisor has not filled this role.

One reason the President's Science Advisor cannot have a significant impact on major Executive decisions is because of the way OSTP was organized. The OSTP is an "invention" of Congress and the Science Advisor does not have "White House immunity." Should the White House staff share any documents with the advisor, he would have to surrender them to any of the 535 Members of Congress who could call and request his presence on the Hill. Members of the White House staff would not have to take such documents to the Hill. Consequently, in sensitive matters, the Science Advisor is not trusted by the Executive Branch. Unfortunately, this gap widens over time and the Science Advisor loses his influence at the highest levels.

The question here is, can the legislation for OSTP be revised to eliminate this restriction, and if so, would OSTP then be able to carry out the policies recommended in this document?

Department of Science and Technology

A Department of Science and Technology could have merit because it would elevate technology to the cabinet level and therefore stand a better chance of influencing presidential decisions. A department level organization would offer the advantage of having technical matters receive more national attention.

A Department of Science and Technology could become the center for collecting and evaluating information on new developments in materials, structures, advancements in electronics, and waste mitigation technologies. It could gather data from foreign sources so that the U.S. could stay informed about the directions being taken by other industrial nations. A Department of Science and Technology could lay out plans years in advance so that the U.S. would be better prepared for future events.

However, a new department would become one more body in competition with other departments and would not have much influence in the Congress. For example when the Department of Energy was formed, it combined the Federal Energy Management Agency, which was a regulatory body, with ERDA which was a research and development agency with weapons production. The results obtained by this formation have to, a large measure, been disappointing. In any case, $1.7 billion for energy technology has been included in the FY 1989 budget for science, basic research and development. Of that amount, little will go toward development that would benefit the private sector. In the early 1980's, development, or demonstration projects as some were called, got out of control when too much money was appropriated for projects that did not appreciably advance the state of the technical arts. In the interim, millions of dollars were lost as contractors rushed to the money trough.

Council on Technology

What is needed is an organization that could influence key policymakers in both the Executive and Legislative Branches. The Council on Technology membership would include representatives from departments and agencies within the Executive Branch, the Congress and the private sector. There would be more representatives from the private sector than from the government to assure that government technology programs serve a useful purpose in increasing the U.S. share of the international market.

While this would be a new organization and therefore experience "growing pains" the annual cost of operation would be insignificant compared to a new department or new foundation.

A National Council on Technology could be a means of obtaining industry/government consensus within the framework of the U.S. Government. This council could recommend research and development programs for government investment purposes. It would provide "routes of communication" among government agencies and between industry and government that would be outside the very highly compartmentalized budget process.

The Council on Technology membership would have to be made up of people with distinguished credentials in technical disciplines. To the extent possible, those with practical industrial experience in the technical arts and sciences should make up the membership.

How the Council would function, where it would be located, how it would be staffed, and what authority, if any, it might have, is a matter for pre-legislative debate.

But, as in the case of all the organizations studies by the Task Force, the Council on Technology would have its drawbacks. The Council would be a loosely organized body with its members having little loyalty to the organization itself.

The Council could become unwieldy and those who might join for the prestige might not participate to any meaningful extent. At best it would only be an advisory board in a city with numerous advisory boards.

National Policy and Technology Foundation (NPTF)

A National Policy and Technology Foundation could also elevate technology in the government and assure that decisions which depend on technical success are made on a sound basis.

As envisioned, this organization would be an independent agency in the Executive Branch and would be governed by a 24-member board. The organization would consist of a National Information Office, an Office of Policy, Analysis and Assessment and various Councils. It would include several existing government agencies which were identified in Section 5 of H.R. 2165.

An NPTF could:

1. Collect, organize and disseminate comprehensive international and domestic data;
2. Analyze national problems and opportunities and assess national policy alternatives—their interdependence and interaction;
3. Provide for national policy review and consensus generation; and
4. Implement and facilitate legislation and functions that Congress deems cannot be satisfied by existing agencies, including in particular, trade competitiveness and the creation and deployment of civilian technology.

This organization would have the advantage of bringing several existing activities together, all of which are involved in matters that influence policy decisions. Having them under one organization could provide an effective means of elevating technology in the Federal Government.

On the other hand, this organization would not have much more influence in the Congress because major policy would still be made through the annual budgeting process.

A Proper Organization

In general, large organizations, government or private, tend to become inefficient with top management too far from the work to be effective. Compartments and subcompartments form, and internal warfare follows. The organization takes on a life of its own and the primary objective becomes one of supporting the organization instead of programs. The original mission gets lost in the shuffle of daily business. Meanwhile, expenses mount as the organization struggles to support itself, often by indirectly appealing to Congress.

The National Aeronautics and Space Administration (NASA), the National Science Foundation (NSF), and the National Bureau of Standards (NBS) all have excellent reputations, perhaps because they are small. They all have their own unique disciplines and products. A merging of any of these agencies could be counterproductive.

In spite of these concerns, an organization is needed. An organization responsible for promoting the development of technologies could issue statements on specific policies involving the enhancement of specific technologies through education, research and development, and by recommending other laws and regulations which affect the strength of U.S. industry in worldwide competition. It could provide communications within the government and between the government and private sector. Hopefully, the breadth of influence would be such that it couldn't be easily ignored. Such an organization could be in constant communication with the president as well as the Congress. It could draw on the Office of Science and Technology Policy, the National Research Council, the Office of Technology Assessment and the General Accounting Office for support. At the same time appropriate executive agencies could also provide statistics and information as needed.

Arden L. Bement, Jr. sees a need for a means to establish policy and wrote:

> . . . I believe the most effective policies will be those that assist the private sector in doing the right things in acquiring new and existing technologies from anywhere in the world that they exist, shortening the time required to apply these technologies to new or improved products and services, and exploiting technology to achieve competitive advantage through more cost effective management and production methods. . . .[19]

Federal and National Laboratories

The Task Force believes that return on investment in government sponsored applied research and especially development should be significantly improved. Rising costs, the decline in the value of the dollar, and enthusiasm for new program ventures will force increases in department and agency budget requests. However, the Congress is no longer in a position to appropriate ever increasing sums of money for federal research and development and, therefore, a method for the selection of programs on a national priority basis is overdue.

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[19] Arden L. Bement, Jr., Vice President, Technical Resources, TRW, letter to Chairman Buddy MacKay, September 11, 1987.

The objective is to channel work at the federal laboratories into programs that are needed by industry, especially medium and smaller companies. Firms like AT&T Laboratories, IBM, and a number of other larger corporate research institutions have less need for support from the national laboratories.

There is a secondary reason for making better use of our laboratories which relates to productivity in the labs. When a private firm is over-extended, it "cuts" expenses; sometime by closing factories and other operations. Not always, but in general, this action results in an opportuntiy for the firm to regain its profitability. Closing government facilities is politically next to impossible. This constraint emphasizes the need to invest in research and development more wisely so that these facilities can be utlized more effectively. We need a firm, steady technology policy which takes advantage of the expertise in the national laboratories.

The use of national and federal laboratories to support industry has been marginal at best. With the exception of the mission-oriented laboratories, the "labs" are much better at performing basic research than they are at developing technology for industry.

On September 25, 1987, Dr. Alan Chynoweth wrote to Chairman MacKay concerning the national laboratories saying:

> . . . Several of these laboratories can potentially offer some excellent professional staff, major facilities and support personnel that could play a greater part in enhancing industrial competitiveness. However, in most cases their missions, cultures and pace do not clearly mesh with the needs of industry. To overcome these differences will require close involvement of industry personnel on site and personnel exchanges. Special efforts will have to be made to bridge geographical separations between these laborataories and industries on the one hand, and to universities on the other. And again, strengthening the role of the national laboratories is not a substitute for, but must be complemented by corresponding strengthening of research and development in industrial organizations.
>
> Ways in which the government could increase the usefulness of the national laboratories to industry include, in addition to those mentioned earlier:
>
> Eliminating as far as possible restrictions on the flow of technical information and intellectual property while ensuring fair compensation or rewards to those organizations that supported the development of the technology. . . .[11]

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[11] Alan G. Chynoweth, Vice President, Applied Research, Bell Communications Research, letter to Chairman Buddy MacKay, September 25, 1987.

Dr. Karl Willenbrock noted that while MITI did not have industrial "know-how" they acted as the catalyst in continuing to move Japan to new industrial accomplishments. The national laboratories can play the role of catalyst in bridging the gap between universities and industry.

> . . . In recent discussions with Japanese industrial leaders, it was asserted that MITI does not have internal industrial know-how but rather uses various industrialists as advisors on major policies and programs. Thus, in working out a new program involving the industrial sector, MITI has in-depth and continuing assistance from company executives. There is also a high degree and mutual trust and respect between governmental and industrial officials which facilitates the timely launching of programs in response to new technological opportunities. . . .[12]

As mentioned previously, we already have the laboratories and we will continue to authorize funds for them in the years ahead. Consequently, the practical option is to obtain greater returns for the investments and to channel those returns into areas where industries, large and small, can obtain benefits. These benefits should be directed toward minimizing industrial risks in manufacturing commercial products and in reducing the period from product concept to market.

In a letter to Chairman Buddy MacKay, Alan Magazine wrote:

> . . . It is widely agreed that the contribution of the federal labs to U.S. competitiveness is inadequate. They need to be more effectively organized and need to establish closer links with the U.S. private sector. Some observers believe that they have become an inefficient bureaucracy and need to be scaled down so that more resources can be freed up for the private sector. There is no doubt that technology transfer between the federal labs and the private sector needs to be improved. Direct government assistance should be provided to industries and sectors involved in core technologies that are the building blocks of U.S. competitiveness. The intent is for the government to work with the private sector to identify core technologies that have an impact on our ability to be at the cutting edge of a wide range of products and processes. . . .[13]

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[12] F. Karl Willenbrock, Executive Director, American Society for Engineering Education, letter to Chairman Buddy MacKay, September 22, 1987.

[13] Alan H. Magazine, Council on Competitiveness, letter to Chairman Buddy MacKay, September 29, 1987.

In a letter to Chairman Buddy MacKay, Arden L. Bement, Jr. presented his comments:

> . . . First, I believe it is important to distinguish between establishing capabilities in advanced technologies and exploiting these capabilities for competitive advantage. While the latter role is best performed by the private sector, the government could do more in performing the former role. Technologies developed at universities, federal laboratories and other research and development organizations, including industrial laboratories and IR&D programs, require considerable refinement and risk reduction before proof of commercial feasibility can be demonstrated. . . . This is a messy process and the key to competitive advantage is to complete this process at the lowest cost and least time.
>
> This risk-reduction process, if unfocused, can involve duplicative efforts throughout an industry during the early stages of market development, the so-called "pre-competitive" stage. Such efforts can be highly wasteful of scarce research and development resources within a company, an industry and indeed a nation. It is during this so-called "pre-competitive" stage that the Ministry of International Trade and Industry plays a national leadership role in Japan in shortening the lead time for market entry for advanced technologies. The method used by MITI is simple: (1) involve industry in determining the advanced technology development and investment priorities, (2) share the investment with industry on a "shared risk", "shared benefit" basis, and (3) terminate government investment when the program goals are achieved (i.e., when competitive forces can best take over). If managed properly such an approach can increase competition by increasing the numbers of potential competitors with capabilities in the emerging technology. However, such a model requires an acceptable working definition of "pre-competitive", careful selection of the critical technical barriers to be overcome, and diligence in terminating government investments when commercial exploitation should take hold.
>
> . . . Also, such policy development has inherent complications concerning "Who chooses what technologies to invest in?", "How should the risks and benefits from such investments be shared between government and industry?" and "What should the Federal Government bring to the table besides money"? Finally, the political difficulties of quickly

> concentrating resources for highly-focused, critical-mass technology development programs are many . . . .[14]

CONCLUSIONS

1. The Federal government needs to take immediate steps to commit Federal research and development organizations to support industry in overcoming the trade deficit.

2. An organization should be created which can successfully respond to the following criteria:

   a. To the degree possible, while recognizing the need to preserve the "separation of powers," create a body which can transcend the executive and legislative branches of government and recommend technology policy for government agencies to execute.

   b. This body could elevate the level of importance of technology in government policy decisions across the complete range of national issues.

   c. It could be organized to include elite engineers and scientists in order to incorporate the knowledge and experience essential to provide qualified judgment in making decisions on technical matters.

   d. Overall, its primary purpose would be to strengthen the U.S. industrial base in manufacturing and services.

   e. It could collect appropriate information from international and national sources which it would then analyze to derive long-term national technology strategies.

   f. It could review the activities of U.S. consortia and cooperative groups engaged in technology programs, evaluate the programmatic balance of activities among these groups, and evaluate the overall potential in terms of national objectives.

   g. It could actively seek advice and consult with firms in the private sector in order to formulate suggested policy and identify priorities for government research and development programs.

   h. It could coordinate its activities with the various economic councils and organizations to obtain information for predictions on the results of various policies.

3. The Task Force believes the need exists for a position of Under Secretary or Assistant Secretary for Technology Policy for each department and agency in the Executive Branch that is engaged in technical affairs to report to the organization cited in number 2 above. In addition, the Congress could establish technology repre-

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[14] Arden L. Bement, Jr., Vice President, Technical Resources, TRW, letter to Chairman Buddy MacKay, September 14, 1987.

sentatives in each committee in the Senate and the House which has jurisdiction over technical matters to also advise this organization.

4. The Task Force has also concluded that there is an abundance of people in the federal and national laboratories with outstanding capabilities There are also laboratory facilities and equipment that span a wide range of technical areas. In the opinion of the Task Force, a large percentage of these resources are underutilized. The Task Force therefore believes that these resources, when they are not needed for critical defense work, should be fully committed to helping resolve national economic problems.

CHAPTER 2—TECHNOLOGY TRANSFER

ISSUES

There is evidence that suggests that technologies under development in the federal and national laboratories are not being disseminated efficiently.

In many cases the applied research sponsored by government is not relevant to industrial needs.

DISCUSSION

The Federal Government has been engaged for many years in trying to expedite the spread of technology among government organizations and from government to industry Public laws have been created to expedite this transfer. Organizations inside the government have been formed to facilitate it. But, in spite of these efforts technology transfer is sluggish at best. The primary reason that technology isn't being transferred is that much of the work in research laboratories is of little or no use to industry. In some cases, industry is not aware of the work underway in the laboratories. In other cases industry fears that work accomplished by them will be passed on to their competitors. In still others, government procedures for transfer inhibit effective working relationships.

In other cases industry suffers from a "not invented here" complex. For these reasons, billions of dollars of investment in research and development that could be useful to industry will not be effectively used in developing new products and processes.

As Dr. John P. McTague, Vice President of Research at the Ford Motor Company said:

> The greatest leverage can come not from the development of a technology itself, but from what happens after it is developed—the creativity of application. Beyond that, even after hardware has been made, the ability to recognize how it could be beneficially modified often leads to previ-

> ously unimagined, and enormously useful additional applications.[1]

Principles of Technology Transfer

The most elementary and essential ingredient in any exercise of technology transfer seems to be a person-to-person element. People of different professions, fields, or orientations frequently enhance transfer when they bring their individual skills and perceptions to bear on the problem. People who are skillful at crossing the traditional lines between disciplines and institutions are important to successful transfer.

Positive transfer activity requires a willingness on the part of both the "giver" and the "receiver". There must be incentives for each side to participate and additional incentives for successful technology transfer. Engineering managers must perceive the transfer process as important and integral to their responsibilities. Given both the uncertainty of optimum techniques for technology transfer and the relatively infrequent incidence of transfer activity, it is important for both the giver and the receiver, for example, a federal laboratory and a commercial enterprise, to each have internal advocates or champions of transfer programs. Technology transfer agents or brokers can assist in expediting technology transfer.

There are primarily two types of technology transfer. The first is the transfer of a discrete item. The second type is probably the form that has the greatest long-term value but is less tangible and defineable. It is a transfer between people on an on-going basis with the continuous mixing of knowledge and ideas as an experiment or project progresses from inception through maturity. One example of this is the "BIG D" fusion experiment at GA Technologies in San Diego where U.S. and Japanese scientists, engineers and technicians have worked side by side for several years. In this work, each side has shared information and ideas. This transfer process is more of an art than a science. Although traditional engineering/technology skills are essential, sensitivity and communication skills are also required in the technology transfer process.

While the transition time from fundamental research to commercial application can be a multi-year process over two decades or more, we frequently expect the transfer and successful adoption of technology to take place almost instantly. Part of the misunderstanding involving a reasonable time-frame for a transfer of technology stems from the perception that "transfer" means receiving an already packaged piece of usable technology. Rarely is a technology transferred that doesn't require some development or technology-improvement work on the part of the recipient.

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[1] Joint Hearing on "Technology Transfer" before the Committee on Science and Technology, House of Representatives and the Subcommittee on Energy Research and Development of the Committee on Energy and Natural Resources, U.S. Senate, September 4, 1986. Testimony of Dr. John P. McTague, Vice President, Research, Ford Motor Company.

Dr. Edwin B. Stear, Executive Director of the Washington Technology Center expressed his views to the Committee. An effective method of transfering technology involves direct transfer of professionals between organizations.

> . . . To illustrate this point, I would like to tell an anecdote relating to the Bell Telephone Laboratories. . . . While walking through the halls of the Laboratory, I noticed there were two kinds of badges being worn by people I encountered. So I asked the fellow who was escorting me, "What are these two kinds of badges?" He said, "Well you see my badge. I work for the Bell Telephone Laboratories. That other guy, he is wearing a Western Electric badge. Those people work for Western Electric." And I said, "What are they doing in the research laboratories?" To which he replied, "That is how we transfer technology. If you go to a Western Electric plant, you will find some people working there with the Bell Telephone badges as well." So I assert that people exchange is the best way to transfer technology.[2]

International Flow of Technology

Another aspect of technology transfer is that which occurs between nations. One of the earliest examples occurred between West Europe and Russia. During the 1600's, West Europeans visited Russia in increasing numbers. As a result, the Russians became aware of the civilization of Western Europe. After Ivan died in 1696, and Peter the Great became the sole czar, he organized an embassy which he, himself, accompanied as one Peter Mikhailov. As Peter Mikhailov, he visited factories, shipyards, schools, arsenals, docks, and hospitals. "In Holland he worked as a carpenter in order to master the technique of shipbuilding. He induced craftsmen and technicians of all sorts to return with him to Russia in order to train Russians to a mastery of European techniques." [3]

Japanese are very efficient in improving and applying technologies developed by others. It is more cost effective to copy than it is to invent. Americans seem reluctant to copy the work of others. On the other hand, the Japanese are also quick to invest and cooperate in development as stated previously, in programs such as the "Big D" fusion program. They have also invested in and are cooperating with the Oak Ridge National Laboratories on robotics for use in the nuclear industry.

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[2] Hearing before the Subcommittee on Energy Research and Development of the Committee on Science, Space, and Technology, House of Representatives, October 12, 1987. Testimony by Dr. Edwin B. Stear, Executive Director, the Washington Technology Center.

[3] *World History*, Brief Introduction by Joseph Reither, Professor of History, New York University, published by McGraw-Hill, p. 300.

For a number of years the Japanese have been publishing some 10,000 articles themselves, and they contain information about the research that is going on in Japan at all levels.[4]

There is an apparent lack of interest and initiative on the part of many (if not most) American companies to aggressively seek out foreign technologies. Our nation's early history is replete with examples of the consuming drive to borrow ideas, techniques, and technology from other nations. We were energetic and innovative about adapting and applying something new to create something even newer and better. Although as a nation we have developed the reputation of being the consistent creator of frontier technologies, we seem to have grown insular in our interests. Instead of combing the world for possiblities, we are reluctant to make the effort to seek knowledge from other nations. In the process, American commercial enterprise and our national economic base lose out on a rich array of possible profit to be gained from the work of others.

> Today, with many foreign corporations having strong technological positions, the United States may have as much to gain as to lose through free exchange of technical information. Some U.S. based firms do seek out and license technologies abroad, but a broad shift in attitude toward foreign know-how on the part of American corporations seems called for. On the government side, it may be more important to pursue policies aimed at drawing in foreign technologies than to pursue policies aimed at slowing the flow of U.S. know-how overseas.[5]

Technology is also transferred out of the U.S. to other nations. The fluidity of information, goods, and services in today's society dictates little practicality in trying to confine these technologies within American borders. The growing prevalence of multi-national corporations makes this approach of little use. The ultimate goal should be to control only strategically critical technologies. A more positive and productive line of action would be to accelerate the pace at which we turn basic inventions into new products while staying on the leading edge of technology.[6]

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[4] Hearing on "Sharing Foreign Technology: Should We Pick Their Brains?", before the Subcommittee on International Scientific Cooperation, Committee on Science, Space, and Technology, April 27, 1988. Testimony of The Honorable Jay Rockefeller.

[5] Ibid., Testimony by Dr. John A. Alic, Senior Associate, Office of Technology Assessment.

Policies That Promote Technology Transfer

Erich Bloch, Director of the National Science Foundation presented the following framework for technology transfer.

> The basic underpinnings of technology transfer are, first of all, an adequate support for basic research that generates new knowledge; second, the availability of trained people capable of performing research, and the subsequent translation of new knowledge into technology and into products that are viable in the global marketplace; third, communication, collaboration and cooperation among the people and institutions that generate the new knowledge on the one hand, and those that have a need for it on the other hand. People are still the best transfer mechanism for complex concepts, scientific knowledge, and engineering know-how.[7]

In the framework identified by Erich Bloch the role of legislative initiatives in promoting technology transfer become clearer.

1. The Federal Government should provide adequate support for basic research that generates new knowledge which can lead to new materials and products. If the goal of applied research funding is to develop knowledge that can maximize the opportunity for developing both new technologies and marketable products, then the applied research projects should be selected in the first place with marketable products in mind. Government initiatives can play a major role in selecting relevant research topics. For example, in 1985, the Secretary of Energy requested that the Energy Research Advisory Board (ERAB) determine the Nation's energy-related geoscience research needs and review the status of DOE geoscience research and development programs. On February 11, 1987, ERAB filed their report with DOE.[8] In July 1987, the House Science, Space, and Technology Committee conducted a Geosciences Hearing to determine, among other things, how well DOE was responding to ERAB's recommendations. Letters from the oil and gas industry to Sandia Laboratories and DOE cited in the testimony of Dr. Hartley,

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[6] Reich, Robert B., "The Rise of Techno-Nationalism", *The Atlantic Monthly*, May 1987, pp. 63-69.

[7] Joint Hearing on Technology Transfer before the Committee on Science, Space, and Technology, House of Representatives, and the Subcommittee on Energy Research and Development of the Committee on Energy and Natural Resources, U.S. Senate, September 4, 1986. Testimony of Erich Bloch, Director National Science Foundation.

[8] "Geoscience Research for Energy Security", A report of the Energy Research Advisory Board of the United States Department of Energy, February 1987.

Vice President Energy Programs, Sandia National Laboratories, indicate that major elements of the oil and gas industry agree with DOE's program emphasis at Sandia and were able to provide numerous examples of how it was helping the oil and gas industry.[9] It is reasonable that commercial industry have an input on the relevance of research conducted at the federal and national laboratories. By doing this there would be more incentive on the side of industry for technology transfer.

2. The Federal Government should make available to industry trained people who are already working in the laboratories and who are capable of performing research and translating the new knowledge into products that are viable in the global marketplace.

3. Initiatives in technology transfer should also promote communication, collaboration, and cooperation among the people and institutions that generate new knowledge and those that have a need for it.

All institutions generate new knowledge, but universities, national and federal laboratories, and industrial research laboratories are best known for this capability. What these institutions need to know is—what are industry's needs? What industry needs to know is—how can these institutions help solve industrial problems? Therefore, policies that promote communication, collaboration, and cooperation between research institutions and manufacturing institutions are needed. Policies such as cumbersome regulations which serve as inhibitors to collaboration should be removed if maximum use is to be made of the wealth of knowledge and information available in the national and federal laboratories.

Conferences and publications in engineering and science journals are a means of information exchange. However, conferences and journal articles frequently include very detailed information in narrow technical areas. Speakers and writers on many occcasions are only communicating with other reseachers who have devoted their entire careers to the same field. This limitation of conference and journal publications identifies the need for product-oriented tutorial reports which communicate more effectively to industry.

Other measures to promote collaboration between industry, federal laboratories, NSF research centers, and universities, include joint programs where persons from different organizations work side by side toward a common goal. SEMATECH is a new collaborative program in integrated circuit manufacturing process research and development that involves cooperative efforts among many elements of the industry as well as national laboratories and universities. Funding for SEMATECH is being shared between government and industry. The Task Force recognizes that the merits of SEMATECH will not be known for a number of years. In the interim, however, the Task Force encourages the formation of cooperative arrangements in other selected areas of high economic potential and supports joint industry-government funding.

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[9] Hearings before the Subcommittee on Energy Research and Development of the Committee on Science, Space, and Technology, U.S. House of Representatives, July 15, 16, 1987. "Responses to geosciences questions following the July hearings" Dr. D.L. Hartley, Sandia National Laboratories, pp. 239–299.

In fiscal year 1987 the U.S. Government spent approximately $60 billion on research and development. This represents about 50 percent of all U.S. expenditures for research and development. Federal laboratories spent about $20 billion of this. Industry access to the facilities and equipment at Federal laboratories can help improve the ability of U.S. industry to compete in world markets. Increased mobility of personnel between Federal laboratories, universities, and industry can improve technology transfer. It is imperative that we develop policies that encourage and provide for increased personnel mobility. Bold, innovative policies are recommended in this area.

Industry/laboratory exchange programs have been used in only a limited fashion and there is little evidence to determine their effectiveness. Interaction between government and industry at professional meetings and seminars and through technical literature does result in some transfer, but there is insufficient incentive for either party to work diligently at making significant exchanges of technical knowledge. Government engineers and government contractor personnel employed at government laboratories who work on joint industry-government research and development projects should receive increased incentives which would give them a personal stake in a commercial opportunity employing their technology. These benefits should be in the form of royalties and should be based on the employees contribution as well as on the amount of profits received by the private firm which results from the research and development. Clearly we need to invent additional methods for synthesizing the technical knowledge in the national labs with the market orientation and knowledge of the private sector.

> More imaginative programs are needed to create and test new methods, and governmental agencies like the NSF and the Department of Commerce should be charged with seeking new forms of private partnerships in order to develop these programs.[10]

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[10] Joint hearing on Technology Transfer before the Committee on Science, Space, and Technology, House of Representatives, and the Subcommittee on Energy Research and Development of the Committee on Energy and Natural Resources, U.S. Senate, September 4, 1986. Testimony of Dr. Raymond Radosevich, Dean and Professor of Management, Robert O. Anderson Schools of Management, University of New Mexico.

Dr. M.K. Korenko, Manager, Advanced Reactor Development of Westinghouse explained the shortcomings in technology transfer from the private sector viewpoint.

> In my previous assignment on the commercial side of Westinghouse, I headed a corporate pilot program to absorb technology from the federal laboratories and universities. . . . It was a very successful program and transfers did occur. . . . In certain parts of the Corporation, however, the transfer process did not work and we analyzed the reasons why. The important conclusion was that the major obstacles to transfer exist in U.S. industry, not in the federal laboratories. These obstacles, in order of priority, are lack of a market vision, stifling of strategic expenditures to gain short-term economic gains, ignorance of the wealth of opportunities that exist in the federal sector, and a not-invented-here attitude.[11]

Elimination of Technology Transfer Barriers

Congressman Robert Roe, Chairman of the Committee on Science, Space, and Technology asked the General Accounting Office (GAO) to gather data about barriers that might inhibit the transfer of technology from our federal laboratories to the private sector. In response, the GAO surveyed research managers and technology transfer officials at 10 federal laboratories and program officials and/or patent counsels in 6 federal agencies. In addition to summarizing the results of their survey, the GAO report provided an excellent summary of past legislative and executive actions taken on behalf of technology transfer.[12]

Past Legislative and Executive Action

Beginning with the passage of the Stevenson-Wydler Technology Innovation Act of 1980 (15 U.S.C. 3701 *et seq.*) and the Patent and Trademark Amendments of 1980 (35 U.S.C. 200 *et seq.*), the Congress has passed several laws and President Reagan has taken executive actions to enable federal laboratories to more effectively transfer technology to U.S. business by collaborating on research and development and licensing inventions.

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[11] Hearing before the Subcommittee on Energy Research and Development of the Committee on Science, Space, and Technology, House of Representatives, October 12, 1987. Testimony by Dr. M.K. Korenko, Manager Advanced Reactor Development Division Westinghouse Hanford Company.

[12] "Technology Transfer—Constraints Perceived by Federal Laboratory and Agency Officials", *United States General Accounting Office Briefing Report* to the Chairman Committee on Science, Space, and Technology, House of Representatives.

The Stevenson-Wydler Act took a first step to improve the utilization of federally funded technology by directing all federal laboratories to establish an office of research and technology applications to disseminate information about federal products, processes, and services. The Patent and Trademark Amendments of 1980 encouraged the licensing of government-operated laboratory inventions by authorizing federal agencies to grant exclusive and partially exclusive licenses if the agency determines that it is appropriate *and in the public interest.*

The Federal Technology Transfer Act of 1986 (P.L. 99-502, Oct. 20, 1986) amended the Stevenson-Wydler Act to authorize federal agencies to permit their *government-operated* laboratories to collaborate on research and development with other organizations, including businesses, through a cooperative research and development agreement. The intent of the act is to make the entering of these agreements as easy as possible from the point of view of the private sector participant, while protecting the legitimate concerns of the government. Under the act, a laboratory can grant a collaborator title or licensing rights to any resulting invention; but if the collaborator takes title to an invention, the government retains a royalty-free license for its use by or on behalf of the government. The act also provides incentives to federal employees to promote technology transfer by directing federal agencies to (1) pay an employee inventor at least 15 percent of any royalties or other income received, up to $100,000 per year, for any invention and (2) establish a cash awards program for inventions, innovations, or other outstanding scientific or technological contributions, or value to the United States due to commercial application or contributions to the missions of the agency or government.

In April 1987 President Reagan issued Executive Order 12591, "Facilitating Access to Science and Technology." The order implements the Federal Technology Transfer Act by directing the heads of federal agencies to delegate authority to their *government-operated* federal laboratories to enter into cooperative research and development agreements and license, assign, or waive rights to intellectual property, which would include inventions and computer software that the laboratory develops.

Before 1980 the government had the option to retain title rights to all inventions resulting from federally funded research and development, although these rights could be waived under certain conditions. The Patent and Trademark Amendments of 1980 gave small business and nonprofit contractors and grantees the right, with few exceptions, to retain title to federally funded inventions that they make. Public Law 98-620, enacted in November 1984, amended the act by extending its coverage to most of the Department of Energy's laboratories that are operated by nonprofit organizations. However, it specifically excluded Energy's laboratories that are primarily dedicated to naval nuclear propulsion or weapons-related programs, because much of their research and development involves classified or sensitive information.

In February 1983 President Reagan issued a memorandum to the heads of all federally agencies that directs them, to the extent permitted by law, to give all federal contractors and grantees the option to retain title rights to resulting inventions. President Reagan further formalized the 1983 memorandum by including similar language in his April 1987 executive order.[14]

Results of GAO Study

Four major constraints on technology transfer from federal laboratories were identified in the GAO survey. Federal laboratory officials expressed the belief that removing or reducing these constraints would (1) provide more incentives to transfer computer software technology to U.S. businesses, (2) encourage U.S. businesses to make better use of federal laboratory resources, and (3) reduce administrative burdens and time delays for interactions.

The four constraints were identified as:

1. Constraints in Transfer of Computer Software

While recent changes in the law allow federal laboratories to patent and exclusively license inventions, federal computer software is publicly disseminated; thus businesses do not have an incentive to fully develop and market it.

Businesses typically copyright computer software or treat it as a company trade secret. However, longstanding federal copyright law (17 U.S.C. 105) states that copyright protection is not available for any federal government work, and federal policy has been to publicly disseminate unclassified and nonsensitive technical data.

2. Constraints in Conducting Proprietary Research

Because federal laboratories generally cannot conduct proprietary research and therefore competitors can obtain access to research results, businesses are less inclined to enter into collaborative research efforts.

3. Constraints on DOE Waivers of Title to Inventions

The requirement that several of the Department of Energy's contractor-operated laboratories must request the Department to waive its title rights to inventions that they make causes uncertainty and delay and reduces industry interest in getting involved.

4. Constraints in Forming Collaborative Arrangements With Industry

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[14] Ibid.

Federal laboratories, in their efforts to be fair in providing business opportunities to collaborate on research, may institute burdensome and time-consuming procedures that inhibit industry participation.[18]

Technology Transfer Policy Recommendations by Professional Engineering Society

The Institute of Electrical and Electronic Engineers, (IEEE) is the world's largest professional society with a total membership near 290,000. Of these, 240,000 live in the United States. Most of the innovations in electronics technology are published in IEEE literature and presented at IEEE sponsored conferences. Electronics products have an international market near $750 billion per year with growth to near $900 billion per year expected by the year 2000. The United States Activities Board (USAB) of the IEEE developed the following position on technology transfer in the United States.

> We believe that the free exchange of technical information is vital to promoting the growth of technology. It is the position of the IEEE United States Activities Board (USAB) that currently implemented U.S. policy of technology transfer can be substantially improved. U.S. government regulations concerning technology transfer, and their implementation, must be rewritten to foster U.S. leadership in scientific and technological development, to increase innovation and productivity, and to support and maintain essential national security. USAB strongly advocates significant changes in current U.S. technology transfer practices. Industry, academia, individuals and the nation will benefit from these changes.

An underlying, coherent policy, along with consistent, uniformly applied, and readily implementable regulations on technology transfer must be established, replacing or amending the several conflicting policies now in existence. It is important that those in government responsible for the execution of these regulations be knowledgeable of the technologies in question as well as government regulations, Inventions & Security Act, etc. Responsibilities for clearly defined control and implementation of technology transfer must be established, including the assignment of lead responsibility for each type of technology. One single government organization should be assigned as the administering agency. Documentation of these responsibilities will correct the perceived splitting of responsibility among the Departments of State, Commerce, Defense, and Energy, with input from several independent agencies (CIA, NASA, NSA, etc.). Most importantly, any limitations on technology transfer should be reduced to the absolute minimum consistent with national policy, and be administered in an efficient and equitable manner.[11]

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[18] Ibid.

CONCLUSIONS

1. In reviewing government budgets and proposals for applied research and development funding, the criteria described in the technology transfer chapter should weigh heavily in the decision to fund the work.

2. Policies that promote cooperation, communication, and collaboration between universities, national and federal laboratories, and industry should contain incentives which make it worthwhile for the participants to cooperate. These same policies could also promote the mobility of research and development personnel between universities, national laboratories and industry.

3. Policies identified by the GAO that eliminate the barriers to technology transfer from the federal and national laboratories should be implemented. Limitations on technology transfer should be reduced to the absolute minimum through more aggressive action by the departments and agencies responsible for technical development. However, restrictive policies could be periodically reviewed by a formal body to assure that the restrictions imposed are absolutely necessary.

Chapter 3—Federal Budget Process and Deficit

ISSUES

The budget process is inconsistent with the obligations of the Federal Government to meet present challenges in international trade, defense, and preservation of national resources.

The process is much too complicated and fragmented to properly allocate scarce resources to essential areas on a priority basis.

Too many programs are initiated and then underfunded with the result that these programs cannot be managed on a time schedule that optimizes the use of resources. Such programs frequently "drag out" to the point where they are eventually abandoned before any tangible results are realized.

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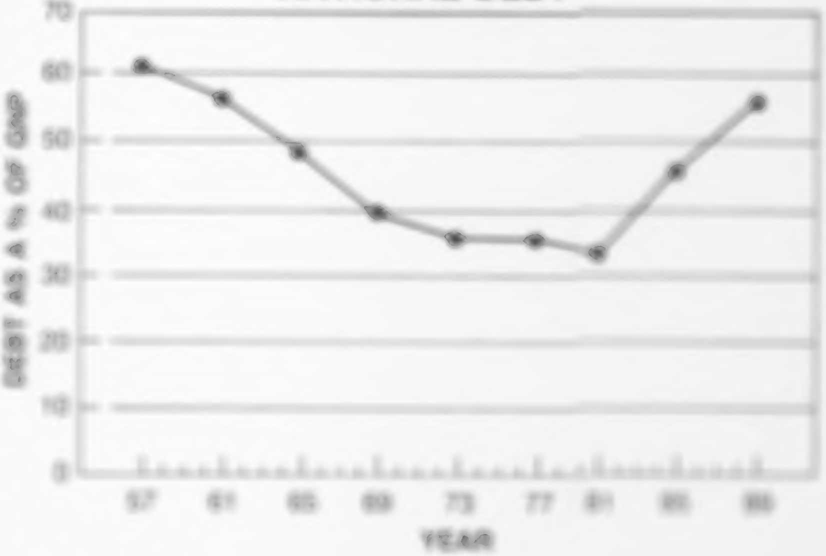
[11] "Technology Transfer in the United States", Policy Position Statement of the Institute of Electrical and Electronics Engineers, Inc., prepared by the United States Activities Board, February 11, 1986.

The budget process is overly influenced by private interests many of which do not coincide with national objectives in technology development.

DISCUSSION

The third largest element in the federal budget is for servicing the national debt. Currently, the debt service is 140 billion dollars. The national debt, estimated and included in the fiscal year 1989 budget, is 2.8 trillion dollars.

CHART B-3A
NATIONAL DEBT

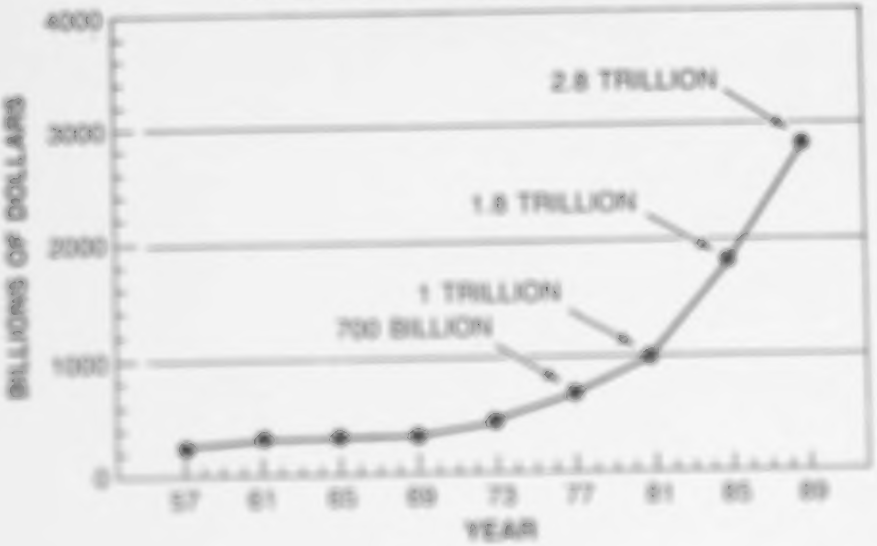


(Trends in Federal Debt: Budget of the United States Government, Fiscal Year 1989, Special Analysis Section, p. E-3.)

If there were no debt, or even if the debt were half of the current amount, and everything else were to stay the same, the investments that could be made with $70 billion future technologies and public works projects could provide for significant future gains toward strengthening the economy.

While the current debt as a percentage of GNP (56 percent) is no more than it was in 1957, there are economic conditions now which did not exist in 1957. The trade deficit didn't exist in 1957, oil import payments were not $20 billion annually in 1957, the U.S. was still the leading industrial nation in the world, other industrial nations had not yet matured, and the United States was still a nation of builders.

CHART B-3B
GROSS NATIONAL DEBT



(Trends in Federal Debt Budget of the United States Government, Fiscal Year 1989, Special Analysis Section, p. E-5.)

The United States is now vulnerable to conditions which can quickly increase the ratio of debt to GNP. Conditions such as a sudden increase in the price of imported oil, a decrease in the export of military equipment from its $25 billion annual level in 1987, or a short-fall in the GNP below the predicted FY 1989 $5,023 billion level.

Under these conditions, confidence in the U.S. economy could drop sharply. A loss in confidence could create a short-fall in foreign investments.

Any tightening of the federal budget has a rapid impact on technology (both defense and civilian) which, compared to the entitlements, is one of the the few areas where the Federal Government has flexibility. The problem with that is, it's technology that can improve manufacturing processes, raise the quality of our products, and assure that the U.S. is at the forefront of new breakthroughs in materials and products.

The federal budget provides for research and development in many areas that reinforce industrial work. When these budgets are decreased, projects are terminated or stretched out to the point where they become ineffective. For this reason it behooves the Federal Government to simplify the budget process in order that priority work can continue without exposure to compromises made to provide for unessential programs.

Under prevailing conditions where much of the federal debt is financed, the discretion to spend is shifted from federal hands to others. When this shift is between Americans who have a stake in the health of the nation, there is less danger. But as the debt grows and the U.S. continues to borrow from foreign sources, the discretion to spend moves off shore to others that have very different loyalties.

The need for economic stability has been voiced by many. At an October 22, 1987 hearing before the Technology Policy Task Force, Dr. Jeff Schott noted,

> The basic problem is that the United States economy continues to spend much more than it earns, and, to date, the shortfall has been covered by huge infusion of foreign goods and capital . . . and the United States has had to maintain relatively high real interest rates to attract funds from abroad, and the very size of this U.S. borrowing has turned the United States in a few short years from the world's largest creditor to the world's largest debtor nation.
>
> The United States cannot continue its deficit-spending spree at recent levels for the simple reason that foreigners are hesitant to finance ever-growing U.S. deficits. Private foreign investors began to shy away from the U.S. market earlier this year (1987). Indeed, in the first five months of 1987 there was no net inflow of private foreign capital into the United States. In essence the U.S. current account deficit was financed by intervention by foreign central banks. How long that can go on is debatable, but it is not a sustainable situation.[5]

A recent copy of a current popular magazine which is read by many middle class *Americans*, contained the following:

> An enduring political delusion is that a tax increase will correct an unbalanced budget. 'Mathematically speaking, increased revenues should reduce the deficit,' says Daniel Mitchell, director of tax and budget policy of the watchdog group Citizens for a Sound Economy. But politically speaking, they do not. Special-interest politics encourages legislators to spend all the additional revenues and then some.

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[5] "Technology and Economics in a Shrinking World," Dr. Jeff Schott, Hearing before the Technology Policy Task Force of the Committee on Science, Space, and Technology, October 22, 1987.

> A study by Ohio University economists Richard Vedder and Lowell Gallaway concludes that for every additional dollar government takes in, it spends an additional $1.58. Since 1981, federal revenues have increased $255 billion, but spending has increased $324 billion.
>
> Thomas Jefferson wrote, 'I wish it were possible to obtain a single amendment to our Constitution . . . taking from the Federal Government the power of borrowing'.
>
> . . . the answer to national challenges is not more spending but more considered and careful spending of the huge amount of revenue you already give your government . . .[2]

The Budget Process

The Task Force received numerous documents from the private sector encouraging "STABILITY IN GOVERNMENT." This advice came from both professional societies and private corporations. Part of the instability such as changes in administrations and Members of Congress, is of course, incorporated in our system of government. But other instabilities are not preordained. Rather, they result from unplanned and uncoordinated work on the part of the government. Such is the case of the annual federal budget cycles, which actually run 15 to 18 months and consume an inordinate amount of time (and expense) on the part of government managers, professionals and clerical help.

Federal budget procedure is one of the primary causes of instability in the government, especially as it affects development and technology.

Annual budgets are debated in Congress for the first 6 to 12 months of each year. Programs have to be defended over and over again, to the point where Members may not even remember what the basic purpose of a program was in the first place.

At a hearing before the Technology Policy Task Force, Dr. Lew Branscomb said:

> The OMB does their special analysis of the budget to look at the research and development content after the budget is all finished. They don't know what it is until it is finished. Nobody looks across the President's budget in any serious detail at the research and development trade-offs until after the budget is put to bed.[3]

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[2] *Reader's Digest*, March 1986, Ralph Kinney Bennett, pp. 49-53.

[3] Technology Policy Task Force of the Committee on Science, Space, and Technology Hearing, "Communications and Computers in the 21st Century," June 25, 1987, p. 93.

The authority of the authorizing committees has been depleted and there is currently no efficient mechanism for multiyear authorizations. Their authority was partly compromised by the Budget Impoundment and Control Act, partly by the creation and increased responsibilities of the Budget Committee and, in some cases, by the failure of the Senate to even consider authorizations for certain areas of technology. The multilayered budget procedures complicate Congressional review of programs and introduce more opportunity for dissent than they do intelligent decisions based on national need and technical merit.

Why Authorizing Committees are Essential

The Congress is responsible for maintaining oversight activities to assure proper pursuit of the programs authorized. (This function is frequently referred to as "micromanagement" by federal agencies.) Without oversight, the "checks and balances" become limited to "self policing" by the agencies themselves. To continue funding countless programs *year-after-year-after-year* with little or no measurement of the results, promotes waste and eventually drains the economy of needed resources.

An essential element of the responsibilities of Congress is to maintain vigilance over the programs it legislates. The job is not completed when legislation is passed—it is just beginning. To live up to these responsibilities, Congress can draw upon the expertise of the Office of Technology Assessment, the National Research Council, and the General Accounting Office. But the responsibility for excellence in oversight lies clearly with the authorization committees. This means that it is incumbent upon the Congress to assure that its support agencies and staffs have personnel educated and experienced in the technical matters associated with the various programs. Authorization committees have staffs with disciplines and expertise in the areas they authorize. But oversight is ineffective unless the authorizing committees have the clout to command the respect of the agencies. When appropriation committees preempt them, they destroy one of Congress' primary tools in assuring the proper conduct of research and development. Recipients of research and development funds serve the hands that feed them.

But the complete answer does not lie solely in correcting the abuses of the federal budget process. Of equal importance is an urgent need to choose the most essential programs and activities for investment. The Congress should also assure that such programs are expertly managed and objectives met on time and within the funds budgeted. When the Executive Branch recognizes that a program is inappropriate, it should be terminated without reprisal, for development work, by its very nature, is risky.

Technology for Commercial Use

With regard to providing for development programs which could support new products in the private sector, John A. Alic stated:

> The U.S. Government, cannot assume that expenditures for scientific research will automatically translate into the commercial products and processes vital for an internationally competitive economy. Nor can it assume that expenditures on military research and development will contribute broadly to the civilian technology base. If governments wish to support commercial technology development, they must do more than support [basic] research.
>
> Many American companies, for example, could benefit from programs aimed at the development of generic technologies with broad commercial relevance. Examples include: applied research in microelectronic devices; combustion processes and automobile safety; disciplines such as engineering design; the science base for manufacturing; common technical concerns such as lubrication and wear or structural integrity. They could also benefit from improved mechanisms for the diffusion of such technologies domestically. To fill research and development gaps on both a technology-specific and an industry-specific basis, the existing system—small in scale and largely experimental—of government-supported centers for generic and cooperative research and development could be broadened and strengthened.
>
> The need is generally to bring the right kind of technical knowledge to a given problem; this is more difficult than it may seem because the problem will often be narrowly defined, requiring highly specialized expertise. An organization may not even know that it is missing a piece of the puzzle: no one with the needed perspective—perhaps a single person with critical skills in engineering or science—can be found within the company.[9]

However, the 8% increase in research and development included in the fiscal year 1989 budget is not encouraging.

> The ability of the Nation to meet global competition, to provide for the national security, and to improve the qual-

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[9] John A. Alic, Office of Technology Assessment, "Technovation [illegible]," [illegible], Elsevier Science Publishers, B.V. Amsterdam.

> ity of life for all citizens depends in part on national investments in science and technology. In FY 1988 national spending for research and development is projected to total about $132 billion, a real increase of about 3 percent over 1987. Of this amount, about $65 billion is expected from federal spending, $63 billion from industry, and the balance from universities, colleges and other nonprofit organizations. The growth rate between 1987 and 1988 is projected to be the lowest in this decade, and is attributable both to tightening federal budgetary constraints, and, in the private sector, to corporate restructurings and other factors.[5]
>
> In the United States, military needs dominate government research and development expenditures. Priorities determined by the Department of Defense set research agenda in aerospace and in many electronics firms; they also have a good deal of influence in universities. Technological spin-offs from military and space projects funded by government or conducted in federal laboratories tend to be long-term and indirect. While these spin-offs sometimes lead to major classes of new commercial products or processes, serendipitous results are neither planned nor guaranteed.[6]

There is a fairly common misconception that more research and development funding yields greater results. This is not always true. Consider the results from such programs as the Department of Energy's Coal Liquefaction and Gasification programs in the late 1970s and early 1980s which included several pilot plant projects. In spite of adequate funding several of these projects failed to produce much in the way of new technology. What might yield greater results is better judgment and planning and a simplified budget process which minimizes overlap between committees.

> The 1989 budget provides significant increases for research and development programs in key agencies including:
>
> selected research and development programs of the Department of Defense such as the Strategic Defense Initiative and the Advanced Tactical Fighter;
>
> most of the research and development programs of the National Aeronautics and Space Administration including the Space Station, Project Pathfinder, and other space science and technology programs.

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[5] *Special Analyses Budget of the United States Government, FY 1989*, p. J-1.

[6] John A. Alic, Office of Technology Assessment, "Technovation 4" (1986) 153-167, Elsevier Science Publishers, B.V. Amsterdam.

basic research support by the National Science Foundation including the establishment of Science and Technology centers;

support in the Department of Energy for initiation of construction of the Superconducting Super Collider (SSC), and for a 5-year, $2.5 billion clean coal technology demonstration psogram; and

Biomedical and AIDS research and development.[1]

The way in which authorization priorities are established is critical to our future. The merits of each of the above programs could be argued ad infinitum. But, what are the priorities? They should be argued on the basis of urgent need for the common good, technical merit, overall lifetime cost and probability of success.

The above programs are not directed towards greater technical support for the private sector to improve our trade balance. About a third of the items included in the above list, have little or no potential for supporting U.S. industry in the near future. But it is the fragmented budget process itself which lacks a "caution indicator" that is activated when budgets differ from national problems.

Basic research is again supported with a 6% increase. This is essential to our long-term strength in technology and should not be compromised. And, one or more of the aforementioned programs may well be essential for long-term strength. But, what are the priorities?

Development (technology) on the other hand is less understood than science—a curious circumstance since science is often more abstract. One aspect of development that is understood, however, is that it is usually much more expensive than basic research. It's also much more difficult to terminate a development project than a research grant or experiment. Development involves design, purchasing materials and components, fabrication, instrumentation, testing and then going back through the cycle when the results fail to measure up to orginal goals, which is inherent in development.

This is the best reason to assure careful and well guided planning of Federal Government research and development. Apportioning research and development funds based on the power of one lobby versus another guarantees the success of competitor nations, for while we waste our money, time, and talent chasing false goals, they will methodically make technical advancements and dominate one market after another. The Koreans and the Japanese are particularly able to pursue carefully prepared national goals. Yet, both are democracies.

The Special Analyses section of the budget continues with:

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[1] *Special Analyses Budget of the United States Government, FY* [illegible], p. [illegible]

> **At the same time, the 1989 budget continues to propose reductions in programs that are not an appropriate federal responsibility and which should be left to the states or the private sector for needed investments. These include large reductions in the energy technology programs of the Department of Energy, as well as elimination of selected programs of the Department of Commerce.[8]**

Another fact that supports a movement away from development which might otherwise benefit commercial industrial products relates to the emphasis on military equipment. The Task Force favors a strong defense force. But in cases like high maneuverability aircraft, stealth, and the Strategic Defense Initiative, technology "spin-off" to commercial products may be very limited.

Sixty-five percent of the $62.5 billion for Fiscal Year 1989 (obligations) is for military research and development. This includes SDI and the Advanced Tactical Fighter. But, it also includes the National Aerospace Plane, a program with additional commercial potential.

Another element of the research and development budget, $5.2 billion, is for the Department of Energy (DOE). But this also includes science. So, it is difficult to determine what investments pertain to technology (development) that could have potential benefits for U.S. industry. But, with a steadfast adherence to a national policy on technology, vast investment gains would certainly be possible and highly probable. At the present time, however, the DOE has consciously pursued a "no development policy" while continuing in the energy area with more studies and conceptual designs. Curtailing development and replacing it with paperwork seldom bears any fruit.

Multiyear Authorizations

During the 99th Congress, the House and Senate addressed the need for a multiyear authorization cycle for research and development.[9]

As the emphasis on reduced federal spending grows, the task of making priority and trade-off decisions on authorizations for specific research and development programs will likely become even more difficult.

We believe that implementing a multiyear research and development authorization process could help alleviate the pressures caused by an annual authorization cycle, provide additional time for the committee to analyze a greater number of research and development activities, and give the Executive Branch adequate time to comply with Congressional requests . . . We also believe that a multiyear authorization process could help push the Executive Branch into acquiring a long range perspective on research and development. Such a perspective is needed to support any father movement towards long range research and development planning based upon defined national objectives. In addition, such a process would serve as an important first step towards improving research and development budgeting as a whole and enhancing the stability of research and development programs. . . .[10]

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[8] Special Analyses Budget of the United States Government, FY 1989 (1988), p. J-3.

[9] Report by the Comptroller General of the United States, "Multiyear Authorizations for Research and Development," June 2, 1987, (letter B-[illegible]) p. 1.

. . . the annual authorization cycle, by its very nature, inhibits the movement toward long range planning; since research and development programs are authorized every year. . . . Without long range planning, research and development decision-makers cannot easily identify and explore the validity of basic assumptions about program operations and economic conditions. Long range planning and budgeting techniques are needed for many research and development areas—like energy—where the planning horizon often extends beyond 5 years. Moreover, because of the time constraints inherent in the current process, the Congress is not able to inquire into all the problems that need future attention and the research and development agencies and OMB-OSTP cannot supply enough information on emerging future issues.[11]

. . . time constraints and lack of adequate information prevent the Congress from fully analyzing the large number of cross-agency programs, research and development programs that do not clearly fall within the 'mission' of any one agency. . . . At this time, however, information on these and other government-wide issues is extremely fragmented and not readily available to Congressional decision-makers from the (Office of Management and Budget) OMB, (Office of Science and Technology Policy) OSTP, or the agencies.

Over the years, we have strongly supported the idea of a multiyear research and development authorization cycle. This process could lay a foundation for Congressional inquiry into existing programs and new initiatives. At the same time, it could strengthen the Congressional oversight process for research and development. . . . a multiyear authorization cycle could encourage longer range decisions.

If research and development budgeting as a whole is to be improved, then a multiyear research and development appropriations process would also eventually need to be implemented.[12]

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[10] Ibid., p. 7.

[11] Ibid., p. 9.

[12] Ibid., p. 11.

If the Congress is to better determine which programs to fund, whether the research and development agencies are allocating their financial resources appropriately, and if funding or program changes are necessary, then the research and development agencies and OMB need to provide more complete budgetary and planning information. This information should link (1) specific research and development programs to the agency's mission and national objectives; (2) ongoing research and development work and future programs, and (3) specific research and development programs in one agency and similar work in other agencies.

A multiyear research and development authorization process would be a first step towards enhancing program funding stability since financial resources would be authorized for 2 or more years. Long term research and development programs would be less susceptible to interruptions, and facilities and equipment could be better maintained since program managers could more easily determine the amount of funds that might be available in the future. Furthermore, staff levels would also be less subject to interruptions if scientists, researchers, and managers knew that funds were authorized for several years. A multiyear authorization cycle could provide this needed sense of security to research staff members.[114]

A multiyear authorization cycle, while not eliminating all difficulties, could significantly reduce the pressures of the current annual authorization process. Such a cycle could . . . increase inter-action between the Congress and the Executive Branch during the entire budget process.[115]

While OMB and OSTP are certainly needed to provide comprehensive planning and budgetary information and to help implement any long range research and development planning activities, it is the research and development agencies that have access to the detailed program information needed by the Congress to authorize these programs on a multiyear basis. Therefore, careful attention must be given to the role of the research and development agencies in the decision-making process.[116]

The need for stability in funding research and development programs is well recognized by industry as Robert A. Frosch of General Motors stated:

> Research has a tendency to take a long time compared to both product cycles and political cycles. Nobody can complete a real research job in a period of time much shorter than a presidential term—certainly not in a period shorter

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[114] Ibid., p. 7.
[115] Ibid., p. 9.
[116] Ibid., p. 10.

> than a Congressional term. Research and development proceed at a pace that is out of synch with the pace of a business's decision-making.
>
> Financial support for business seems to come increasingly from markets and groups who regard two and a half weeks as an eternity and a quarter as being the age of the universe. So sometimes research and development fail because nobody has enough patience to let them succeed.[16]

Congress is caught in a difficult position. To close the gap between revenues and expenditures in the Federal Government, something must be done to raise revenues. There is a definite sentiment against further taxation. If productivity can be increased, greater revenues can be raised without increasing the level of taxation. It is also significant to note that the 1987 Nobel Prize for Economics was awarded to Dr. Robert Solow of the Massachusetts Institute of Technology for his work demonstrating that the most important component of economic growth is technological innovation. Whatever the Federal Government can do to increase the economic "pie" will prevent the need for a more wrenching redistribution of the nation's wealth.

Hopefully, the need for a "Federal body" to consolidate the power to select programs for technology development will be carefully considered by the National Economic Commission which was established in the Budget Reconciliation Act for 1987 to examine, among other things, the following:

> "methods to reduce the federal budget deficit while promoting economic growth and encouraging saving and capital formation," and
>
> "a means of ensuring that the burden of achieving the federal budget deficit reduction goals of the United States does not undermine economic growth and is equitably distributed and not borne disproportionately by any one economic group, social group, region or state."

Heraclitus of Greece is credited with the aphorism, "Nothing endures but change." Keeping pace with technological change must be left to industries and business communities. The Congress can support the efforts of these agents of progress but cannot supplant them.

The amount of federal funds budgeted for research and development, which includes science as well as technology, may or may not be adequate. Without a policy which identifies national priorities federal funds probably will not be effective in meeting national needs. Such a policy is requried for the United States to retain industrial preeminence. There is no reasonable way to evaluate the budget. This is particularly true in the area of development. It is obvious, however, that the amount budgeted for research and development is small compared to other components of the budget. Eighty seven percent of the budget is spent on retirement income, social security, defense, paying the interest on the national debt, and medicare. The other 13 percent is for everything else it takes to provide for the common good. Less than one and a half percent is available for general science, space, technology and energy.

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[16] *Mechanical Engineering*, December 1987, "GM's Healthy Pain," by Robert A Frosch, Vice President, GM Corporation, pp. 24–25.

However, the trend of a rapidly increasing debt is more alarming and can result in a lack of investor confidence. At a hearing before the Technology Policy Task Force, Dr. Schott said:

> The budget crisis, in particular, limits macroeconomic remedies. In this area of making the climate better for technological innovation, the main prerequisite for a national technology policy and one which reinforces U.S. industrial competitiveness has to be a sound U.S. budget policy. The first step must be a compromise between the Congress and the Executive Branch which produces substantial cuts in the federal budget deficit, and I can only hope that the shock waves from Wall Street this week (October 1987), which led the President to finally send a delegation up to Capitol Hill to discuss with Congressional leaders about the need for such budget cuts, will produce real and substantial results and will not be a fig leaf to get through another Gramm-Rudman deadline.[17]

CONCLUSIONS

The Task Force maintains that the budget deficit must be significantly reduced by this and future Administrations and Congresses if the intolerable burden on future generations is to be ameliorated. It also recognizes that properly planned budget reductions could restore faith in the Federal Government.

1. There is an urgent need to simplify the budget process. Technology policy is being made by the funds budgeted annually for various programs instead of establishing definitive long-term programs with specific objectives and milestone schedules from which budgets could be established and results carefully monitored. The authority of the authorization committees should be restored to prevent funding of programs that have not been carefully reviewed and evaluated. Multiyear authorizations with a provision in the

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[17] Hearing before the Technology Policy Task Force of the Committee on Science, Space, and Technology, "Technology and Economics in a Shrinking World," October 22, 1987.

annual budgeting process that assures out year appropriations could be made to conform to schedules to the extent that funding can be made available.

2. Funding research and development is not enough when there is great concern in Congress for the budget deficit. The Task Force concluded that the Committee and the Congress could look carefully at existing government programs in all areas and beginning with the FY 1990 budget, place the highest of priorities on the economic security of the nation. With such priorities, and recognizing budget restrictions, the influence of private interest groups might be reduced when it comes to preparing appropriations bills in the years ahead.

CHAPTER 4—DEFENSE RESEARCH AND DEVELOPMENT

ISSUE

A strong defense is essential to assure continuation of the liberties of the American public. Defense is the first and most fundamental priority of the Federal Government. Nevertheless, the Task Force notes that a strong defense is dependent on a strong economy. If our nation is to successfully compete with Asian and European countries for international markets in commercial products and simultaneously compete with the Soviet Union in the defense arena, then we must learn to make dual use (both defense and commercial) of research and development funds provided by the U.S. Government.

DISCUSSION

In the early 1980's there was a consensus that our defense capabilities had to be upgraded. As a result,

> More of our tax dollars went into defense, more of our GNP went into defense, more of our industrial capacity went into defense, and no doubt more research went into defense. It may be hoped that we are now on the path toward better or, at least, safer relations with the Soviet Union, and one hopes that will allow us to readjust our priorities. Obviously, the world and all its citizens would be better off if all nations were able to concentrate on civilian rather than military needs; not just in science but in all areas. But in spite of that it is important that we keep federal funding of commercially relevant research and de-

> velopment at a level that allows us to compete with other countries.[1]
>
> Military spending has to be justified on military grounds. Efforts can be made to minimize the economic drawbacks of such spending and maximize the spin-offs for the civilian economy. But if creating civilian technology is the end goal, then it is best done through civilian research and development.
>
> Defense is a form of public consumption. If Americans want to have more defense consumption, they have to be willing either to cut other forms of public consumption or to raise taxes. . . . Defense is financed with funds borrowed from the pool of savings that would otherwise be available for capital investment to enhance future productivity.[2]

The dynamics of the international market include competition for U.S. high-tech markets. Japanese firms have taken the lead in many semiconductor and computer areas, as well as in most of the fiber optics industry. European consortia have challenged American leadership in aerospace technology. Our competitors also have achieved wide success in such fields as biotechnology, robotics, machine tools, and ceramics. In most of the fast growth industries, the United States is losing its market share. In 1986, the United States had its first full year trade deficit in high-tech products.

Defense Spending

Roughly, during the same period when the United States is witnessing loss of industrial competitiveness, U.S. Government expenditures on defense research and development have grown dramatically. Whereas in 1980, the U.S. used 50% of its federally funded research and development for defense purposes, in 1987 fully 69% of the federal research and development funds were devoted to defense projects (estimated to be 71% in 1988). In comparison, Japan spends only 3% of its government-funded research and development on defense projects, while West Germany spends 12%.[3] Of the national investment in research and development—approximately $125 billion in 1987—the Federal Government will provide about $60 billion. Only about $18 billion of the federal investment in research and development is not related to defense.

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[1] IBM Science Paper, dated June 1, 1988, Rough Draft, Provided to the Honorable George Brown, June 13, 1988 for meeting with Dr. R.E. Gomory, Senior Vice President for Science and Technology.

[2] Lester C. Thurow, Dean of the Sloan School of Management, M.I.T., "The Economic Case Against Star Wars", *Technology Review*.

[3] Leonard Lederman, Science and Technology Policy and Priorities: A Comparative Analysis, Science Magazine, September 4, 1987.

Defense-related projects now account for one-third of the total public and private research and development expenditures in the United States. In fact, in constant dollar terms, government sponsored, nondefense research and development funding has actually declined since 1980. Morever, the distribution of government sponsored defense research and development has changed. While funding of weapons development has increased, funding of basic and applied research has declined dramatically, from 26% of the DOD research and development budget in 1965 to less than 10% in 1987.[4]

> Defense spending accounted for 6.6 percent of GNP in the United States in 1986, but it accounted for a considerably higher percentage of the products and services in some areas of the country. In California, for example, defense accounted for about 9.3 percent of GNP. The same imbalance was found among industries. In California, defense accounted for 16.3 percent of total manufacturing output, 55.8 percent of output in the aerospace industry, 38.9 percent in the communications and electrical equipment industry, and 22 percent in the electronic components and semiconductor industry.[5]

For many private corporations defense is their primary if not exclusive business. For example, in 1986 General Dynamics received $8.0 billion in defense funds, General Electric received $6.8 billion, McDonnell-Douglas received $6.6 billion, Rockwell International received $5.6 billion, and General Motors received $5.1 billion. With defense funds of $150 million, Brunswick Corporation ranked 100 on the funding list.[6] It is highly unlikely that this funding led to significant quantitites of international sales.

Pressures to reduce the budget deficit as well as progress in arms control negotiations may lead to future reductions in the U.S. defense budget. Even without these events, defense experts should be continuously looking for ways to reduce defense expenditures and make more efficient use of budgets.

Examples of Technology "Spin-offs" From Defense Work

The U.S. military establishment recognized the revolutionary nature of the 1940's breakthrough in semiconductor materials and concluded that semiconductor devices had great potential for military applications. The Department of Defense funded a substantial fraction of the germanium point contact transistors developed and manufactured by Bell Telephone Laboratories (BTL). The Army, Navy, and Air Force each funded BTL about $1 million per year to refine a working transistor that BTL had built. The Air Force program was run by Dr. Otmar Stuetzer, a project engineer at the Wright-Patterson Materials Command who recalled that in 1940 Dr. Gorelik of the USSR had published a description of a silicon carbide, point contact transistor. Dr. Gorelik's device was not completed, but the research illustrated many of the important principles of a point contact transistor. Military funding of BTL's work continued from the 1948–1949 time period well into the 1950's. Much of the early emphasis of research was on the development of a transistor that could be manufactured with consistent performance characteristics.[7]

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[4] Michael E. Davey and Genevieve Knezo, "The Federal Contribution to Basic Research," CRS Report for Congress, July 23, 1987.

[5] Rauch, Jonathan. "After the Boom," *National Journal*, December 19, 1987, pp. 3193–3198.

[6] Defense Almanac.

Also in the 1940's, Dr. Al Brodzinsky, who was then a semiconductor research scientist at Naval Research Laboratory, pointed out defense services began funding transistor and microwave diode research just after BTL announced their fabrication of the point contact transistor.[8]

Mr. Howard Steenbergen who also worked for the Air Force Electronics Laboratory at Wright-Patterson AFB during this time, recalled that BTL did the basic research work with corporate funds but the services funded a significant part of BTL's investigation of how to manufacture devices in large quantities. Mr. Steenbergen pointed out that the Air Force funded Texas Instruments fabrication of a silicon bipolar junction transistor and that TI announced the first working device at a meeting at Wright-Patterson AFB. This work was motivated by the Air Force's desire to obtain transistors with temperature characteristics better than those of germanium.[9]

Mr. Steenbergen also pointed out that defense funding was almost entirely responsible for the development of GaAs IC technology. He recalled that in the early years defense funds were oriented toward the development of manufacturing process equipment. As an example, electron beam lithography was built at Westinghouse with defense funds, but somewhere along the way it was decided that this work should be funded by industry. Afterwards this technology became dominated by the Japanese.[10]

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[7] Personal communication by telephone from Dr. Otmar Stuetzer to Technology Policy Task Force staff.

[8] Personal communication by telephone from Dr. Al Brodzinsky to Technology Policy Task Force staff.

[9] Personal communication by telephone from Mr. Howard Steenbergen to Technology Policy Task Force staff.

[10] Ibid.

An important aspect of early government funding of semiconductor technology was the use of government sponsored research and development as leverage to develop a technology that had commercial promise. It was anticipated that commercial use would follow and when it did, it was expected that the commercial sector would be the driving function for further technology evolution.[11]

Several important principles are illustrated in these examples.

1. Most basic transistor research was funded by private industry.
2. Defense agencies quickly recognized the promise of this new technology for defense applications and continued funding basic research as well as development.
3. Many incremental improvements to semiconductor devices and integrated circuits were made as a result of defense funding.
4. Defense funds were also concentrated on development of improved manufacturing processes and new manufacturing tooling.
5. The commercial use of this new technology was of importance to the military services and influenced their choice of contractors.
6. The services recognized that commercial applications would lead to reduced costs for defense programs.
7. Defense funds were the catalyst that promoted large investments from the private sector.
8. Although one may think of a transistor as evolving from vacuum tube technology, we claim it was the ladder process (revolutionary or radical new development) that led to the invention of the point contact germanium transistor. In addition, technology transfer from the USSR may have contributed to U.S. success.
9. All other developments in semiconductor devices and integrated circuits were a product of cyclic development (the repeated introduction of incremental, evolutionary improvements).

It is this process of incremental improvement that—following the initial great ladder-style invention of the transistor—has given us every year larger and better computer memories. In the past 20 years of incremental improvement, we have come from one bit on a chip to one million. Incremental improvement is also the process that each year gives us higher resolution display screens, better quality printers, and so on.[12]

Furthermore, in areas where the United States has not been competitive, it has lost—insofar as technical factors are concerned—usually *not* to radical new technology but to better refinement, better manufacturing technology, or better quality in an existing product.[13]

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[11] Ibid.

[12] Hearing before the Technology Policy Task Force of the Committee on Science, Space, and Technology, House of Representatives, November 4, 1987. Testimony of Dr. Ralph E. Gomory, Senior Vice President for Science and Technology, International Business Machines Corporation.

The Probability of "Spin-offs" From Defense Systems

According to Robert Reich of the Kennedy School of Government, "commercial needs and defense needs are further apart than they once were".[14] Many electronics systems developed for defense use now have more rugged environmental requirements than do those developed for commercial applications. Reliability requirements for defense electronics frequently exceed those of commercial products.

It is customary for defense systems to achieve high reliability through the use of exhaustive testing and certification programs. The combination of defining the most severe operating requirements and designing for performance differs from commercial production where acceptance has to be built in to assure high production yields.

Paul Lewis explains, "as modern weaponry becomes more sophisticated, the technology it requires is becoming increasingly disassociated from civilian needs".[15] Nonetheless, some "spin-off" is possible and essential to civilian products. As computer technology enters its newest phase, it is especially important that the government assure that maximum commercial use is made of the Pentagon research and development progam for Very High Speed Integrated Circuits (VHSIC). In this program, chips with ten times the transistor density and 100 times the speed of current chips are being developed.

The Pentagon generally is more willing to take risks and do long-range research and development than a commercial corporation. Because the sophistication of modern weapons systems has emphasized the use of advanced electronics and the commercial electronics industry has great potential for continued high growth (perhaps $600 billion in growth during the next 12 years), our defense electronics industry should once again become a resource for "spinning-off" many products into the commercial sector.

At a time when the United States has a large trade deficit, the Task Force encourages the DOD to use its research and development resources to promote commercial applications whenever possible.

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[13] Ibid.

[14] Eric Alterman, "How Pentagon Spending Undermines the Economy;" *Business and Society Review*, Winter 1985.

[15] Paul Lewis, "Military Spending Questioned;" NY Times, November 11, 1986.

Defense Procurement

Military procurement practices may have an adverse effect on the efficiency and long-term health of many American industries. The Pentagon tends to emphasize performance over costs. Contractors are not encouraged to develop efficient, cost-effective production methods or invest in new production tooling. The negative aspects of the procurement process can weaken the ability of firms to compete in the international commercial market. In many instances of low production quantities, is not cost effective to spend the money required to minimize production costs. However, with new computer integrated flexible manufacturing process technologies now being developed, low quantity production runs can become as cost effective as large quantity runs once the initial investments are made. Therefore contract awards that favor suppliers who are willing to make significant manufacturing process investments, would help strengthen industries.

Some defense contractors follow a "buy in" process where they propose low cost estimates to win a proposal and then go over budget, knowing that the Defense Department will reimburse them. Jacques Gansler finds that the cost of an average defense contract increases 45% over the life of a typical project.[16] Eric Alterman argues that "many contactors continue to prosper in a noncompetitive cocoon, as DOD subsidizes their inefficiency, at a cost to the firms themselves whose business practices become lazy and eventually self-defeating".[17]

Defense industries are not sufficiently encouraged to operate efficiently and keep costs down. Senator Charles Grassley says that he has seen Pentagon documents showing that "our defense industry on a average is operating at one-third of normal efficiency." [18] Former Secretary of the Navy, John Lehman, asserted in an interview with New York Times Correspondent Richard Halloran that, "many defense contractors show a contempt for the customer", because each is a sole source for a particular weapon or piece of equipment. Complacency in this area has meant high costs, poor quality, and late deliveries.[19] Technology developed in this atmosphere has limited commercial utility.

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[16] Jacques Gansler, "The Defense Economy," Cambridge, MA: MIT Press, 1980, as seen in op. cit. Stowsky, p. 35.

[17] op. cit. Eric Alterman, "How Pentagon Spending Undermines the Economy."

[18] Richard Halloran, "To Arm A Nation: Rebuilding America's Endangered Defenses," New York: MacMillan Publishing, 1986, p. 182.

[19] Ibid.

Draining Human Resources

Defense procurement has inadvertently drained many qualified engineers and technicians from the commercial sector. A substantial number of engineers have shifted to the military sector, because of the availability of stimulating technical challenges. In 1978, the National Science Foundation found that 16.2% of the nation's engineers and scientists worked primarily on national defense.[20] These percentages were far greater for some fields. For example, the NSF found that 60% of the nations aeronautical engineers worked in the military sector, as well as 35% of the electronics engineers. Professor Lloyd Dumas of the University of Texas estimates that at least 30% of America's scientists and engineers are now engaged in military-oriented work.[21] Professor Dumas reports that in many of the most important engineering and computer science fields, a great proportion of faculty positions remain unfilled, affecting our future technology capacity and training. "This diverts manpower resources from commercial growth without a lasting contribution to long-term economic development".[22]

Technology Transfer

A vast amount of technology which might otherwise not be developed by commercial industry is developed by the Department of Defense. One major issue raised is—what to transfer to the commercial sector and what not to transfer. Defense secrets, technologies like the "quiet propeller" machining technology sold to the Soviets through a subsidiary of Toshiba, should be closely guarded and held internally as long as practical. But, unclassified technology should be transferred quickly to expedite the flow of technically updated products to the market. Issues of technology transfer that are especially applicable to defense are treated here; the larger issue of technology transfer is treated in another section.

Classification Practices

Information and technology are classified because it inhibits transfer to those foreign powers that might make military use of the information. In fact, we are especially concerned about the transfer of information or technology that might be used against the United States. Nevertheless, classification inhibits not only technology transfer to foes, it inhibits communication throughout the defense industry. It makes use by our commercial industry impossible.

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[20] Gordon Thompson, "The Militarization of High Technology," edited by John Tirman, Cambridge, Mass: Ballinger Publishers, 1983.

[21] Lloyd Dumas, "The Military Burden on the Economy," Bulletin of the Atomic Scientist, October 1986.

[22] op. cit. James Botkin, Dan Dimancescu, Ray Stata, "Global Stakes: The Future of High Technology in America." p. 74.

Several features of our classification system are worthy of review. Those making decisions on classification issues are motivated to err on the side of over-classifying. For the most part personnel responsible for classification within the defense industry are not responsible for communication of information to other defense contractors and they are not responsible for transfer of technology to the commercial sector. Therefore those making classification decisions are not required to trade-off classification versus technology transfer and other national objectives.

Laws with severe penalties are available to protect classified information from public disclosure. Failure to transfer technology to commercial industry is not a crime. In many instances information is "born classified" and will remain classified unless it is proven to be unclassified. Therefore, the burden of proof rests on those wishing not to classify rather than on those wishing to classify.

Classification of information inhibits or in some cases prohibits peer review and severely restricts publication options. Although these are not perfect methods for assuring high quality technical work, experience has shown that they are important. Of course, peer review and publications are convenient mechanisms for the transfer of defense technology to the commercial sector.

Independent security systems and different security clearance systems between the Department of Defense and the Department of Energy inhibit the transfer of defense information between these Executive Branches.

In general, classification practices are designed to inhibit the transfer of information and technology. Little consideration is given to the negative consequences of our classification policies. Those in the defense industry that champion technology transfer are fewer in number, more restricted in authority, and lack the power of the law in comparison to those responsible for classification practices.

Patent Practices

Our nation has always shown concern for fairness by not permitting individuals or private companies to exclusively benefit from government-sponsored research and development. Without protection from competition, commercial industry may lose interest in converting defense products into commercial use.

Research and Development Practices

One may broadly divide the evolution of technology into three technical phases: research, development, and manufacturing. If an idea is to transition through these phases and turn into a product that can be marketed, communication and technology transfer among those working on these phases is imperative. In particular, those conducting the development phase must be able to effectively take the results of the research phase and convert this research into a manufacturable product for which a market exists or can be developed. When one of these phases, for example, the research phase is done in isolation from the development phase (as it is done in many Department of Defense laboratories) products rarely result. Isolation of the development and manufacturing phases has resulted in the development of many products that cannot be economically manufactured. Attention to the relationship of these three phases within the defense complex would enhance the transfer of defense technology into commercial products.

National Security Export Controls

Although there is general agreement about the need for export controls on military products, the current criteria and mechanisms used may be counterproductive to U.S. industrial competitiveness. A National Academy of Sciences panel concluded:

> U.S. national security export controls are not generally perceived as rational, credible, and predicatable by many of the nations and commercial interests whose active cooperation is required for an effective system. In their view the scope of current U.S. controls encompasses too many products and technologies to be administratively feasible. . . . There is limited but specific evidence that export sales have been lost or forgone because of uncertainty or delays in the licensing process and because of concern about future license approvals, availability of spare parts and components, and possible reexport constraints. Once changes in buying preferences occur, they may require large investments of time and effort to reverse.[23]

An illustration of the problem is: Should a $10,000 music synthesizer that contains a $500 computer disc drive be considerd a military or civilian product? Should the manufacturer be forbidden from selling the synthesizer to the Soviet Union because selling the disc drive alone is prohibited? [24]

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[23] National Academy of Sciences, Committee on Science, Engineering, and Public Policy. "Balancing the National Interest: U.S. National Security Export Controls and Global Economic Competition," National Academy Press, Washington, D.C., 1987, pp. 15-16.

[24] Rasky, Susan F. "What Is Good for Security May be Bad for Business," The New York Times, October 18, 1987, p. E5.

The Academy panel recommends "restricting controls to technologies that are easily identified with military uses" which will, it contends, make national security controls more effective while reducing any deleterious effects on U.S. exports.[25]

Impact of DARPA on Commercial Industry

Because of the success of one DOD agency in developing technology that has impacted commercial industry, it is worthwhile to review the testimony of Dr. Craig I. Fields to this Committee.

> Although our role is to support National defense, much of the technology we develop is so called dual use technology with a significant application in the commercial sector. We consider these spin-off benefits in aid of the National economy to be of considerable importance.
>
> DARPA has the largest advanced research program in the world in computer science and technology. That program has been responsible for the development of artificial intelligence; for computer time sharing; for computer graphics; for packet-switched computer communications; and most recently for the development of the fastest supercomputers in the world. Our research in artificial intelligence, or AI, has spawned many new companies and made the U.S. the world leader in that area. Our computer communications research led to the ARPANET, and that technology is now a de facto standard in use through the U.S. There have been many other spin-off effects from our computer research in areas such as teleconferencing, training technology, and office automation technology—like the mouse on the Apple Macintosh.

CONCLUSIONS

As the major recipient of federal research and development funds and as the Department who performs most of the technology development work, the DOD is encouraged to develop and implement procedures which will expedite the transfer of useable technologies to the civilian sector.

The Task Force recognizes the continuing need for a strong defense but reminds the DOD that as in World War II, a strong defense is made by a strong national industrial base.

The Task Force notes that defense contracting procedures could be overhauled to enable more firms, especially DOE's weapons systems laboratories and subcontractors, to directly participate in bidding on contracts.

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[25] National Academy of Sciences, Committee on Science, Engineering, and Public Policy. "Balancing the National Interest: U.S. National Security Export Controls and Global Economic Competition," National Academy Press, Washington, D.C., 1987, p. 15.

CHAPTER 5—STATE AND LOCAL GOVERNMENT

ISSUES

State and local governments share in the responsibility to maintain a strong economy. Much of the progress needed to make major improvements in the nation's standing in the global market, both in products and services, rests with these governments.

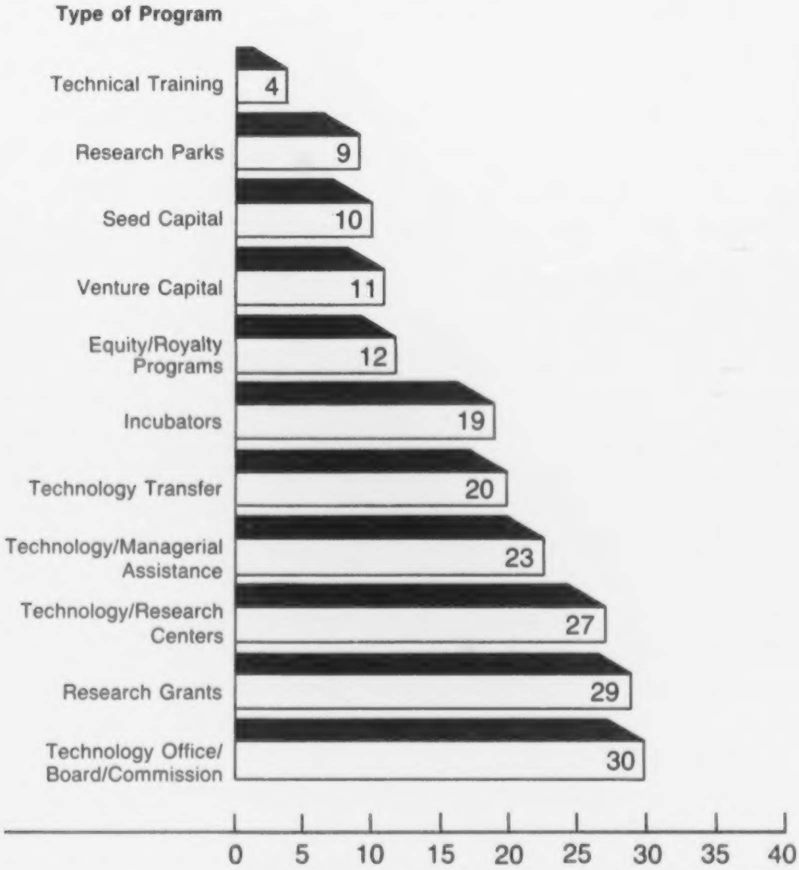
DISCUSSION

The Federal Government's capabilities to strengthen the economy are limited. If the United States is to regain lost ground in developing, manufacturing and marketing new products, it will be up to many of the state and local governments in conjunction with private companies to make the advancements. State governments are in closer contact with their citizens and many are in a strong financial position and therefore able to float bonds and offer other incentives to industry.

Many state governments have already made considerable progress by providing essential incentives which have attracted and stimulated industry. For example, New Jersey has made significant accomplishments through its Commission on Science and Technology. Foreign trade offices bring foreign investment to New Jersey as well as help businesses sell abroad. Foreign corporations have invested close to $11 billion in American plants and equipment. More than 1,000 foreign firms employ 153,000 New Jersey workers. In laboratories at Bellcore, AT&T Bell Labs, and SRI, New Jersey's scientists are chasing the mystery of superconductivity. The discovery of superconductivity at warm temperatures would revolutionize the use of electricity.

No other nation has the advantages offered by our decentralized form of government wherein state governments can take action to strengthen the economy without the approval of Washington. Chart B-5A illustrates the contributions to technology made by state governments.

CHART B-5A



Number of states supporting technology initiatives, FY 1986; (program expenditures total $700 million).

L. Jones, B. 1986 ***State Technology Programs in the United States.*** The Governor's Office of Science and Technology, Minnesota Department of Energy and Economic Development, St. Paul, Minn. P. 5.

The best way to rebuild our private sector is by providing the right conditions and incentives to stimulate manufacturing on U.S. soil. When the public grasps the full meaning of the global economy, many state and local governments will be in the best position to harness the forces to compete in our domestic market and foreign markets.

Economic problems already affect our standard of living. The National Governor's Association report, "Making America Work," included this definition of our economic status:

> Standard of Living. While trade statistics have received the most attention and have prompted the most concern,

there are signs that the broadest and most meaningful indicator of competitiveness, the U.S. standard of living—family income, adjusted for inflation—would have declined substantially over the last decade had there not been significant increases in the number of families with two wage earners. In short, one reason we are keeping up is because we are working harder.[1]

Recent History of Local Industries

There have been significant changes in the cities, towns, and suburbs since the end of World War II. Changes in the composition of the workforce came along with increases in the population and the creation of suburban areas. But there were other changes in the society which contributed to our present industrial status. These included:

1. A decline in manufacturing for reasons identified in Section E of this report.
2. Labor unions who expected greater compensation without corresponding increases in productivity.
3. A shift in the composition of the workforce from blue collar to white collar office workers.
4. An awakening to the need to protect the environment.
5. An over reaction to risk taking along with a dramatic increase in litigation.
6. A lack of recognition of the progress being made in foreign countries where capitalism and industrial output were growing rapidly.

But in spite of these changes, there were other areas where industrial strength grew dramatically as new technologies were founded and exploited.

Silicon Valley and Route 128, Boston

Silicon Valley and Route 128 around Boston came into existence not through the foresight of legislators, but instead each randomly developed without consideration of initial overall objectives. In some cases, the efforts of state and local government have barely affected, much less altered the economies within their jurisdiction.

Silicon Valley is full of stories about successful gambles, overnight millionaires, and garage companies. But these achievements would not have been possible without people like Lee de Forest who had connections with Stanford University.

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[1] National Governor's Association, Center for Policy Research, *Making America Work, Productive People, Productive Policies.*

Stanford University molded the surrounding atmosphere into one of innovation and excellence. An example of its efforts was the launching of Hewlett-Packard, one of the area's largest, most unusual, and most admired electronics companies. Through the personal guidance of Professor Fred Terman, Stanford's visionary vice president, David Packard and William R. Hewlett set out to commercially exploit a new invention of Hewlett, a variable frequency oscillator which worked more efficiently than more expensive models.[2]

The major impetus for Silicon Valley came from outside the Valley, in fact, from across the country in Murray Hill, New Jersey, home of what was then called, "Bell Labs." It was the invention of the transistor which prompted the electronics revolution at Silicon Valley. As noted by Arno A. Penzias, Vice President for Research at Bell, "without Bell Labs, there would not be Silicon Valley." [3] The transistor's inventor was from Palo Alto, California. He also wanted to make a million dollars. Dr. William Shockley knew of the activity in Silicon Valley through his contacts in the electronics industry. With his move to California, the entrepreneurial chain-reaction began transforming Silicon Valley into a major electronics production region.[4]

Another element that aided in the formation of Silicon Valley was defense spending by the Federal Government. Lockheed's move to northern California in 1956 and the massive purchases of semiconductors by the U.S. Department of Defense played a significant role in the development of Silicon Valley.[5] The invention of the transistor, the inventor's background, the innovative pursuit of technology by Stanford University, the pleasant climate and living conditions, to "just plain luck" were involved in the founding and rise of Silicon Valley.

In Boston, companies began to spin-off from the research labs of the Massachusetts Institute of Technology (MIT) and other colleges prior to World War II. As early as 1930, close industry-university relationships were fostered by then MIT President, Carl Taylor Compton. The massive military spending of the wartime research effort in the 1940's fueled the rapid expansion of the area. During the period from 1955 to 1971, the number of firms in the Route 128 area increased from 39 to over 1200.

But it was not until the politicalization of the forces around Route 128 that the second revival of the area occurred. Tax conditions had worsened, so much so that the nickname of the state had become "Taxachusetts". The desire of a new breed of capitalists rekindled the fires that had forged Route 128 as a high technology center.[6] With the establishment of the Massachusetts High-Technology Council, conditions in the state changed to court new growth.

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[2] Everett M. Rogers and Judith K. Larsen, *Silicon Valley Fever* (New York, Basic Books, Inc., 1986). p. 32–33.

[3] Ibid., p. 35.

[4] Ibid., p. 37–38.

[5] Ibid., p. 39.

Regional Development Planning

One of the first efforts to directly plan and engineer a high technology center was in North Carolina at the Triangle Research Park. It was created in 1960 with the founding of a research and development park of some 6000 acres in the area between Duke University, North Carolina State University, and the University of North Carolina at Chapel Hill. Besides Triangle Park, Bionic Valley at the Utah Research Park was founded in conjunction with the University of Utah.

While these activities deserve recognition, it takes time for a regional center to be successful. A minimum of 10 or even 20 years may be required to translate policies and plans into a major industrial center.

There is a lot more to technological innovation than invention of a new device. A manufacturing base is critical to a productive industrial center. This aspect of the economy has been neglected in recent years, but many states are now "opening their doors" to various corporations and helping them establish new production facilities.

The technological infrastructure includes such items as university links, access to research and development labs, and informal communication links with information resources. The entrepreneurial network encompasses venture capitalists, a technical labor force, and proximity to complementary and competitive enterprise. One of the foremost advantages is the proximity to research and development labs.[7] Another prominent element in the infrastracture is an effective comunication network.

Similar to the communications network, a "grid" of experts and advisors can assist start-up companies.[8] Assistance in obtaining financing and judging software needs or plant and capital equipment requirements are services that a new commercial company might need to help it succeed in the market.

Another element of the technology infrastructure is related to the qualifications of the people engaged in the enterprise.[9] Without a pool of engineers, skilled craftsman and experienced professionals, a new industrial center may not succeed. A key part of the success of both Silicon Valley and Route 128 was the availability of highly motivated intelligent people. In the case of Silicon Valley, the new engineers graduating from Standford University, the faculty of the university itself, all aided in the founding of that area.[10] Route 128, on the other hand, had the services of some 12,000 out-of-work engineers when it began its latest ascendancy.

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[6] Everett M. Rogers and Judith K. Larsen, p. 236–238.

[7] Ibid., p. 7.

[8] Ibid.

[9] Ibid.

Venture Capital

The availability of venture capital is paramount to the success of a regional industrial development. Edward J. Malecki says, "it [venture capital] appears in virtually every inventury of 'necessary' conditions for innovative entrepreneurship." [11] Some regions may find the commercial exploitation of research and development activities highly difficult because of a lack of capital, as has been the case with Research Triangle Park. For example, the south accounted for only 4.2% of all venture capital receipts in 1982 [12] and OTA projections predict slow growth in venture capital accumulation for the south, although evolving markets may have unpredictable effect on the market's makeup.[13]

Accessibility to suppliers, the accessibility to customers and new markets, the accessibility to transporation, to skilled labor, are all critical to private firms and therefore are essential elements in state and local planning.

A social "role model" also influences the entrepreneurial atmosophere. In Silicon Valley, for example, Fairchild Camera started some thirty-five spin-off firms from 1957 to 1970. In each case, the new company was directly founded by a former employee of the parent firm, Fairchild Camera. Intel was one of those spin-offs.

Apple Computer, under the guiding hand of Steven Wozniak, might have failed to leave the design stage, to become the international success it is today, if it had not been for Armas C. Markkula, who prepared the prospectus and secured nearly $1 million in capital to get Apple Computer out of the garage and into the world.[14]

For state and local governments to increase the extent of technology and production there must not only be an "up front" commitment, but also a future commitment on the part of gubernatorial administrations. This overall effort can also have a greater impact upon Federal Government policy, since the regional group will be seen as a representative voice of the state.

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[10] Everett M. Rogers and Judith K. Larsen, pp. 25-43.

[11] Edward J. Malecki, "Regional Economic Development and State Science Policy," Paper prepared for the National Science Foundation PRA Workshop, An Agenda for Science Policy Research, Washington, D.C., 17-18 September 1987.

[12] Jesse L. White, Jr., ed., Report of the Committee on Technology and Innovation, Atlanta, Georgia, Southern Growth Policies Board, 1986, p. 20.

[13] "Technology, Innovation, and Regional Economic Development," p. 8.

[14] Everett M. Rogers and Judith K. Larsen, p. 13.

Cooperation Among Various States to Form Regional Centers

As in the case of I-75, a state effort may not be effective without the incorporation of other states. In each case, the proximity of universities, laboratories, housing, highways, airports, and rail sidings all make a difference and it may frequently mean that such a region covers more than one state. "Interstate cooperation is required if the natural economic dynamics of such regions are to be optimized and their mutual potential to be realized."[15]

There are other reasons for states to cooperate with each other. States with less technology and manufacturing process capability may attempt to form regional centers with other states. Other states which have an older industrial base may see regional centers as a means of diversification and business development to avoid the effects of market collapse.

The question then, is what can states to?

State Programs

First, a state can provide some form of financial aid, direct or indirect.[16] Financing can include tax credits, industrial revenue bonds, and loan guarantees. Direct financing can include allocation of government monies for research and development. Other direct funds can be in the form of venture capital or even seed capital for "start-up" companies.[17]

The state government acts as a policy formulator, recommending courses of action to county, city, and townships.[18]

Other state programs can center on education. California, for example, has attempted to institutionalize this role by establishing the Microelectronics Innovation and Computer Research Opportunities (MICRO) program from which graduate fellowships and faculty research projects will be funded.[19]

Local governments are integral parts of the state and exist through the direct mandate of the state and hence are responsible to the state. But, local governments also have their own resources.

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[15] "Leadership for Dynamic State Economies," p. 84.

[16] "Technology, Innovation, and Regional Economic Development," p. 64.

[17] "Encouraging High-Technology Development," p. 17.

[18] "Technology, Innovation, and Regional Economic Development," p. 54

[19] "Encouraging High-Technology Development," p. 17.

Route I-75

More recently, regions along Route I-75 from the Canadian border to Miami are growing. I-75 may not have all the advantages that Silicon Valley had, but new advantages and different objectives can be just as successful, albeit in a way that is more appropriate to the area. The overriding requirement is to provide the conditions which will stimulate growth.

The Japanese have identified Route I-75 and have invested about 25% of their direct U.S. investments along the 1600-mile route.[20] I-75 is favored because of good routes of communication and the fact that the long string of factories keeps them from becoming dependent on one local labor pool.

Meanwhile, the older inner city manufacturing areas no longer offer advantages essential to compete in today's global economy. land costs are excessive, and the white collar service-oriented labor force in many cities is not qualified to manufacture products.

Corporations, like Ford, Mazda, and General Motors have established plants along I-75. Honda is expanding their plant in Ohio and Toyota is building an $800 million plant near Lexington, Kentucky.[21]

Kentucky paid $12.5 million for the land it bought for Toyota and is spending nearly $115 million for improvements including access roads, a wastewater treatment plant and for worker training.[22]

In spite of these and other accomplishments, considerable effort is still needed at state government levels.

Counterproductive State and Local Laws

Counterproductive laws, regulations, policies, and procedures frequently prevent industry from moving into an area. This is particularly true in the manufacturing area. Even such operations as the manufacturing of printed circuits can have plating operations with liquid waste products which require substantial treatment. Many communities shun such operations. But the long-term future of many communities depend on production. While strict zoning laws genrally benefit everyone, zoning which prevents the advent of new manufacturing operations can eventually hurt a community through loss of employment. Besides, waste products can be successfully treated through the proper application of technology. Most communities want "campus type" industries, generally meaning "office parks" and service sector operations. While the service sector has provided most of the employment gains in recent years, much of it does not contribute to improving our balance of trade. Furthermore, productivity is hard to measure in the service.

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[20] "Cruising into the 21st Century," by Edwin A. Finn, Jr., *Forbes Magazine*, August 24, 1987, p. 80.

[21] Ibid., p. 82.

[22] Ibid., p. 83.

Even utility companies who supply electricity for industrial strength and for conveniences at home, are frequently prevented from adding the plant capacity needed to fulfill their responsibilities as a public utility.

> . . . a growing number of state commissions have refused to allow utilities to recover in rate increases the full construction expenses for projects deemed in hindsight to have been unnecessary or poorly managed. These developments have deeply eroded investor confidence and have led most utilities to avoid major new construction of any kind.[23]

CONCLUSIONS

1. Many state and local governments can significantly enhance the U.S. economy by forming and supporting regional industrial development centers.
2. In order to be successful, these centers should include certain basic elements such as a highly skilled professional cadre and a skilled labor force. They also should have adequate financial support and take advantage of regional strengths and facilities.
3. State governments with strong regional centers can have significant influence on federal legislation that can benefit such activities in their state.

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[23] *Scientific American*, March 1986, Volume 254 Number 3, "Rethinking Nuclear Power," by Richard K. Lester, p. 31.

SECTION C—EFFECTS OF GOVERNMENT POLICIES ON TECHNOLOGY

CHAPTER 1—GOVERNMENT POLICIES IN GENERAL

ISSUES

Instabilities in Government policies, high deficits, high interest rates, and global economics are the biggest reasons industries refrain from long-term investments in development, plant and capital equipment. These instabilities also encourage U.S. firms to enter into agreements with foreign firms wherein the foreign firm (or U.S. owned facility in a foreign country) produces the products which are then marketed in the U.S.

Numerous laws and regulations are overly complex and restrictive, and increase the cost and time for industry to perform efficiently.

DISCUSSION

The Task Force does not believe the government should determine what products industry should develop. This report adheres to that policy. However, there have been times when the government has considered an industry to be so basic to the foundation of the economy, that it intervened. This report cites one case, commercial electronics, that it believes is critical to the future wellbeing of the nation.

There is already a great deal of government involvement in industry and there are presently a great many government policies which control the way technology is developed and employed. Even those regulations that are reasonable and appropriate are often unclear, inconsistent, and inefficiently implemented.

The following chart, C–1A illustrates the time required for approval of medical drugs in 6 countries. Consistency between the different countries or for different drugs within the same country is elusive.

CHART C-1A
Number of Months Required to Approve Drugs in Selected Countries (1980 and earlier)

Drug	United States	Canada	Norway	Sweden	Switzer-land	United Kingdom
Beciomethasone dipropionate	26	8	8	19	7	5
Sodium valproate	5	(a)	(b)	(a)	45	3
Cimetidine	13	8	19	20	10	2
Protiretin	28	(a)	(b)	21	9	(c)
Vidabrine	23	12	(b)	(c)	(c)	6
Somatotropin	15	(b)	(b)	23	10	8
Sodium iodide 1-123	20	(d)				
Diazoxide	40	11	14	(a)	14	(c)
Phospho lipids	14	24	(b)	43	3	7
Amino acids	12	16	(b)	23	7	(c)
Danazol	30	16	17	34	21	6
Prazosin	40	30	27	(a)	10	6
Disophyramide phosphate	54	19	36	80	17	(c)
Propranolol:						
Amhythmias	17	23	9	16	4	5
Angina	17	11	9	16	4	5
Hypertension	18	19	14	16	4	(c)

(a) Under review at agency at time of review.
(b) Not submitted to agency at time of review.
(c) Data not available.
(d) Not available in other countries.

General Accounting Office. 1980. *FDA Drug Approval—A Lengthy Process that Delays the Availability of Important New Drugs.* Washington.

The following chart lists areas where government policies affect industry.

CHART C-B1—GOVERNMENT POLICY TOOLS IMPACTING TECHNOLOGY

Policy tool	Examples
Public enterprise	Innovation by publicly owned industries, setting up of new industries, pioneering use of new techniques by public corporations, participation in private enterprise.
Scientific and technical	Research laboratories, support for research associations, learned societies, professional associations, research grants.
Education	General education, universities, technical education, apprenticeship schemes, continuing and further education, retraining.
Information	Information networks and centers, libraries, advisory and consultancy services, data bases, liaison services.

CHART C-B1—GOVERNMENT POLICY TOOLS IMPACTING TECHNOLOGY—Continued

Policy tool	Examples
Financial	Grants, loans, subsidies, financial sharing arrangements, provision of equipment, buildings or services, loan guarantees, export credits.
Taxation	Company, personal, indirect and payroll taxation, tax allowances.
Legal and regulatory	Patents, environments and health regulations, inspectorates, monopoly regulations, industry regulation or deregulation, product liability laws.
Political	Planning, regional policies, honors or awards for innovation, encouragement of mergers or joint consortia, public consultation.
Procurement	State or local government purchases and contracts, public corporations, research and development contracts, prototype purchases.
Public services	Purchases, maintenance, supervision and innovation in health service, public building, construction, transport, telecommunications.
Commercial	Trade agreements, tariffs, currency regulations.
Overseas agent	Defense sales organizations.

Dr. Don Kash reported in a hearing conducted by the Task Force that the government's role with regard to industry is as follows:

> I guess I would say that my own observation is that government involvement, in fact, is more important in the United States than it is in most countries. There really are three things that government has to do generically. One is, government has to fill some role in funding the research and development end. Secondly, government has to pay a midwifing role between researchers and developers and producers and marketers or deployers, and third—and unless there is something out there I can't find—government in this country has to provide some incentives for the deployment of those innovations, and it has consistently done that. I think this really has to be done sector-by-sector.[1]

Dr. Fusfeld mentioned: "The thing to ask in every case is, what can the role of government be? Not so much should it have a role or not? Because even by the tax laws you're playing a very important role. So you're always in it, but it has to be thought about carefully." [2] Despite all of these policies that affect technology in one way or another, there is no apparent provision in the legislative branch of the government to consider and assure that the cumulative effect of all these policies is in the best economic interests of the nation. Capital availability and cost ultimately depend upon the fiscal and monetary policies of the Federal Government. At present, these policies are seldom, if ever, set in accordance with the nation's competitiveness requirements in mind. A comparison of the United States today to 19th Century Great Britain serves as a reminder of the constant need for careful and practical decisions by government.

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[1] *Hearing on Cooperation in Industrial Research and Technology Development* before the Technology Policy Task Force, July 15, 1987.

[2] Ibid.

CHART C-1C: HISTORICAL COMPARISON BETWEEN GREAT BRITAIN AND UNITED STATES

Great Britain then	United States now
Mid 19th century British science was the envy of the world.	U.S. science is the envy of the world today.
An economic boom began in the early 1850's and continued for 20 years.	An economic boom began in the early 1950's and lasted for 35 years.
In the 1870's, Britain's capital was growing but they chose, without any real debate, not to modernize their aging industrial base.	U.S. industry did not modernize its industrial base after World War 2.
Britain's trading states imposed high tariffs on British goods.	U.S. trading states have imposed constraints on U.S. goods.
Throughout the 19th century, British sold fewer products abroad than they purchased.	The U.S. has had a negative balance of trade since 1981.
The British trade balance did not *appear* to be in difficulty, however, because of surpluses in the *service sector* (shipping, insurance, and financial services).	The U.S. economy appears healthy with low unemployment, but 70% of the Gross National Product (GNP) is in the service sector.
Between 1875 and 1900 Britain's productivity rose at a solid 1.2% per year.	U.S. manufacturing productivity has been rising at a steady rate.
The training of workers did not interest businessmen or the government, while, by 1914, the Germans spent 2.5% of their GNP on education stressing technical training.	The U.S. has failed to stress technical training, while Japan, with half the population, graduates as many engineers as the U.S.
In 1899, Britain sent 28 salesmen to Switzerland to sell British goods where they had to compete against 3,828 Germans.	Americans are shy about sending sales engineers to Europe and Asia and those that do go are generally ignorant of the customs and the language.[3]

[3] World Quarterly, August 1987, pp. 97-109.

The President's Commission on Competitiveness identified the influence of macroeconomic and trade policies on technology. Long-term economic growth has not been consciously pursued by a coordinated economic and technology policy.

Policy coordination is needed not only between economic goals and technological innovation, but also in avoiding contradictory policies pertaining to a single sector or technology. The following chart indicates such contradictions:

CHART C-1D: SOME CONTRADICTORY POLICIES IN THE UNITED STATES THAT AFFECT THE OPERATIONS OF INDUSTRY

Policy	Contradiction
The Environmental Protection Agency is pushing hard for stringent air pollution control.	The Energy Department is pushing companies to switch from imported oil to dirtier coal.
The national Highway Traffic Safety Administration mandates weight-adding safety equipment for cars.	The Transportation Department is insisting on lighter vehicles to conserve gasoline.
The Justice Department offers a guidance to companies on complying with the Foreign Corrupt Practices Act.	The Securities and Exchange Commission will not promise immunity from prosecution for practices the Justice Department might permit.
The Energy Department tries to keep down rail rates for handling coal to encourage plant conversions.	The Transportation Department tries to keep coal-rail rates high to bolster the ailing rail industry.
The Environmental Protection Agency restricts use of pesticide.	The Agriculture Department promotes pesticides—for agricultural and forestry use.

Source: Business Week, 30 June 1980.

There has been no recognizable policy to enhance technology or industrial output since World War II. Clearly there is a need for sound cohesive government policies to meet the objective of regaining preeminence in technology. The Federal Government now needs a strong steady policy that supports technology and industry if we are to maintain a standard of living at least equivalent to the past ten years. Such a policy can not be left to chance and the unpredictable annual budget process.

Instead of being an asset in cultivating industry, the government has been more of an adversary, continuously impeding progress through needless regulations made largely in response to small pressure groups and media magnification.

To a great extent the U.S. competitive decline is illustrated by divergent national objectives between such countries as Japan and the United States. Mr. Dick Heinbach, formerly the Senior Assistant U.S. Trade Representative for Bilateral Trade Policy emphasized the divergences of the national objectives in the following chart:

CHART C-1E: DIFFERENCES BETWEEN U.S. AND EXPORT-ORIENTED COUNTRY GOALS

	U.S. goals	Goals of export oriented countries	What the consequences can be for United States
Government goals:			
Economic Growth	Moderate	High	A declining percent of world market.
Export Growth	No goal except in a few sectors.	High	Lack of policy to broadly stimulate exports.
Savings	No goal	High	Inadequate domestic savings, dependence on foreign capital.
Consumption	No goal	Low	Overconsumption relative to income.
Investment in internationally competitive sectors.	No goal	High	Inadequate investment in sectors that must compete internationally.
Standard of living	No goal	Higher	Accept declining relative standard of living.
Leadership in advanced technologies	High in agriculture, defense, medicine, and space.	High in nondefense industries.	Accept market distortions that erode technology base in nondefense industries.
Trade/current account balance	No goal	Surplus	Accept large deficits for indefinite future and growing debt burden.
Productivity Improvement	No goal	High	Failure to encourage more rapid productivity growth.
Capital Costs	No goal	Low	Higher capital costs.
Means employed:			
Preferential support for certain sectors	Defense and agriculture only.	Targeted emerging sectors.	Lose ground in targeted sectors.
Protection of home markets	Declining industries	Emerging industries	Unable to compete for as large a share of world market as competitors and unable to preempt or retaliate against competitors based in the country. Also leads to widespread dumping in U.S. market.
Cooperation among firms	Highly regulated	Encouraged	Limited opportunity to share costs/risks.

Collusion in market	Prohibited	Tolerated	Victimized by collusive behavior of others.
Foreign investment restrictions	None	Extensive	Distortion of trade and investment patterns, "too many competitors".
Foreign exchange controls	None	Extensive	Distortion of trade and investment patterns to favor local firms.
Research and development subsidies	Mainly defense	Mainly commercial	Overemphasis on non-commercial technologies.
Technology transfer controls	Export only, for security and foreign policy reasons.	Both ways for commercial reasons.	Less attractive partner/source for technology.
Technology protection	High	Low	Declining technology lead.
Debt leveraging	Low	High	Less rapid growth, higher capital costs.
Capital borrowing costs	High	Low	Higher financing costs.
Profit Expectations	High	Low	Higher threshold for new investments.
Business practices:			
Shareholder protection	High	Low	Vulnerability to take over.
Shareholder stability	Low	High	Harder to implement long term strategy—short term financial results focus.
Worker rights	Moderate	Low	More difficult labor-management relations-lower productivity.
Worker welfare costs to firm	Moderate	Low	Higher labor costs.
Export promotion/support	Weak	Strong	Poor export growth.
Government procurement	Moderate discrimination.	High level of discrimination.	Exclusion from foreign government markets where local products are available.
Tax treatment	Favor consumption and nonproductive investment.	Favor savings and productive investments.	Inadequate investment in competitive sectors, higher capital costs. Overinvestment in noncompetitive sectors.
Treatment of big firms	Regulatory	Partnership	Big U.S. firms disadvantaged in international competition.
Corrupt practices	Prohibited	Tolerated	Loss of business due to continuation of such practices in many countries.

CHART C-1E: DIFFERENCES BETWEEN U.S. AND EXPORT-ORIENTED COUNTRY GOALS—Continued

	U.S. goals	Goals of export oriented countries	What the consequences can be for United States
Technical/scientific education support	Moderate	High	Erosion of relative scientific/technical workforce capability.
Government organization:			
Coordination of executive/legislative	Difficult and sporadic	Close and sustained	More difficult to implement sustained strategy; greater uncertainty.
Role of professional bureaucracy	Subordinated to political leadership.	Leadership in policy formulating and implementation.	Less professionalism and continuity in policy and implementation.
Role of political parties	Competitive	One party dominates	Less ability to pursue long range goals in sustained manner.
Centralization of decision-making	Decentralized	Centralized	Less ability to coordinate range of policies toward development objective.
Industrial policy organization	Defense and Agriculture.	All key industries	Inability to develop and implement strategies for strategic industries.
Business/government cooperation	Uneven and sporadic	Close and sustained	Less government understanding of competitive issues and less coordinated effort.

Note.—Two elements were omitted from this chart, Exchange Rate and Employment. These elements have shifted significantly since the chart was drafted. Also, the subtitles were revised for clarity.

The chart speaks for itself. It should be noted, however, that a "no policy" *is a policy.* Secondly, the U.S. position on many of these subjects has substantially contributed to the trade deficit. In some cases the U.S. position has contributed to Japanese success in areas "targeted" by the Japanese. Dr. Frank Press noted, "Starting with the 'smoke stack' industry products and following with high technology products, Japan has emphasized up to now the latter stages of the innovation cycle. The highest priority was given to putting into place the most advanced process and production technology, aggressive pricing, and mass marketing. Japan was content to be the second to the market with new products, believing—rightly so—that better quality and lower cost of its products would displace those of the original innovators."[4]

The Need For Better Global Marketing Information On Which To Base Government Policy

With other nations becoming more competitive, the U.S. Executive and Legislative Branches should actively seek information about the planning and actions taken by foreign governments and how these actions will affect U.S. industry. Industry and government will have to become much more knowledgeable and flexible in the future in order to respond to changes in market conditions. The U.S. Government should maintain contact with other nations who compete in the global market and with U.S. industries so that responses to changing market conditions can be included in government and industry planning. The reality is that in a world of dynamic markets, delays can be very costly to industry and society.

New Policies Needed For Progress

The United States has moved from a nation of "builders" to a nation crippled by laws and procedures and fearful of everything from the caps on aspirin bottles and formaldehyde in new carpets to midair collisions. If the above events occurred, they would result in tragedy for a few but they would have very little effect on the nation. But these are the events which result in dramatic media presentations. Orson Welles proved the power of the media drama in the early 1930's when a radio drama reporting the arrival of visitors from another planet led to mass hysteria.

Federal policies alone may not be able to resolve our economic problems. A general decline in our society is already having a profound effect on all our futures and will lead to a wide range of social problems. While technology can not, by itself, correct societal ills, a strong economy is essential to support programs which can reform society. A strong economy is highly dependent on technology. Our past history is testimony to the influence of technology on our high standard of living.

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[4] Press, Frank, *A High Technology Gap? Europe, America and Japan,* Council on Foreign Relations, New York, N.Y., p. 23.

Environmental Policies

There has been considerable misunderstanding over such national needs as a clean environment. Some believe that protection of the environment is directly proportional to the number of laws and procedures issued. Others believe that we have to restrict industrial growth in order to have a clean environment.

There are cases where companies and individuals should be fined or otherwise prohibited from practices which foul the environment. In those cases, punishment should be appropriate and swift. But, for the most part, existing and future technologies can be brought to bear on environmental protection. As chemical waste brings new hazards, associated remedies can be vigorously pursued and made available. With an anti-industrial policy, however, the technology base and engineering resources needed for this will be unavailable. A large portion of delays imposed in the interest of protecting the environment are counterproductive.

One example of technology to solve environmental problems is "dry scrubbing". Dry scrubbing is a technology currently under development which has already demonstrated that it can be used to significantly reduce acid rain.

The Federal Registers might well receive a "scrubbing" to keep the essentials and eliminate unneeded procedures which result in delays and inhibit industrial growth.

Delays, especially on capital intensive projects, such as mass transit systems, power plants and manufacturing facilities can be enormous and in many instances result in abandonment before completion after large sums of money have been lost. The way large projects such as these are consistently stalled by federal, state and local governments, eventually sap the strength of the firms who would otherwise undertake such projects.

Nuclear energy provides a good case study for the kinds of mistakes, misconceptions, and lack of proper management that can occur.

Dr. George Vendryes explained:

> The position of the American Government on the use of nuclear energy has shifted from strong support through 1976, to great reticence and even strong opposition under President Carter. It then moved to a favorable but restrained attitude in that President Reagan has urged economic forces to take control. American society, whose func-

tioning is based on individual initiative and market forces, is poorly suited for [Government] planning outside military and space programs or the like. The roles played by their respective governments in the field of nuclear power in France and the United States are in no way comparable.

Consent intervention by Congress, often unfavorable to nuclear power, complicates and even paralyzes sustained action by the government. The only area where the need for a long-term policy seems to have been clearly defined is the storage of waste. . . .

American institutions stress a sharing of power between the central government and the 50 States. This greatly facilitates the destabilizing actions of small, determined pressure groups such as the antinuclear movements. In addition, the complexity of U.S. nuclear regulations, the hearings system and the numerous types of available recourse give opponents the means to drag the procedures out beyond all reason.

The issue of construction permits and operating licenses for nuclear installations is further complicated by the organization and functioning of the NRC with its highly bureaucratic methods. The competence and goodwill of its personnel are not in question, but its working environment causes it to implement the regulations in a way in which formalism prevails over sound technical judgment. The procedures become very long and difficult, their course and outcome are uncertain and the utilities are sometimes obliged to install costly, unnecessary systems, which may even ultimately prove contrary to true safety needs.

As in most countries, people in the U.S. are not concerned with long-term energy problems, such as an adequate supply of electricity. The current stability of gasoline and natural gas prices in the U.S. has given a false sense of security to the general public. There is thus relatively little interest in nuclear power matters outside those areas where there is controversy over specific plants. The resulting lack of strong public support weakens the political base for a renewed government and industry program of nuclear power plants.[5]

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[5] *Observations on the Nuclear Power Programs of France and the United States.* Dr. George Vendryes, Atomic Industrial Forum, Inc., February 1986, p. 5–6.

Professor Richard K. Lester, Massachusetts Institute of Technology, has also studied the impediments to providing electricity over the long-term at a price that could help keep U.S. products competitive.

> The system of economic regulation to which utilities are subject has recently served to discourage investment in large capital-intensive power plants of any kind. For privately owned utilities, which supply almost 80 percent of the nation's electricity, state public-utility commissions and the Federal Energy Regulatory Commission control the return on investment by regulating rates. The regulators grant monopoly obliged to provide an adequate supply of electricity to all consumers at reasonable cost; in return they are allowed to charge prices that bring their shareholders an adequate return.[6]
>
> The NRC, moreover, is beset with internal problems rooted in its unwieldy organizational structure. Indeed, several independent investigative committees, including the Kemeny Commission, which examined the Three Mile Island accident, have concluded that the agency may be inherently ineffective in its present form. Its internal difficulties have contributed to arbitrary and inconsistent dealings with licensees, which have increased the cost and financial uncertainty of building nuclear plants. Industry officials have said repeatedly that until the financial risks associated with licensing new plants can be lowered, further nuclear orders are out of the question.[7]

CONCLUSIONS

All branches of government can review, at least biannually their federal registers to assure that outdated and unnecessary restrictions are cleansed from the system. Concurrently, they can review regulations to assure they support the growth and welfare of U.S. based industries. Oversight by the appropriate authorization committees would be of immeasurable value in this regard to revise legislation when it is no longer appropriate.

"Technology policy has to include the other elements of our free society or we cannot compete successfully. Thus, it is our "overall" system that must be competitive with the systems of other countries." [8]

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[6] *Scientific American*, March 1986, Volume 254, Number 3, *Rethinking Nuclear Power* by Richard K. Lester, p. 31.

[7] Ibid., p. 34.

[8] Bruce Merrifield, Assistant Secretary for Productivity, Tehnology and Innovation, Department of Commerce.

American industry can and will compete successfully against other nations when government policies provide the proper incentives to attract long-term investments.[9] These incentives can be incorporated in laws which provide tax and other benefits.

The Congress and the Executive Branch can cooperate in forming policies to rebuild our technology base especially in the manufacturing area.

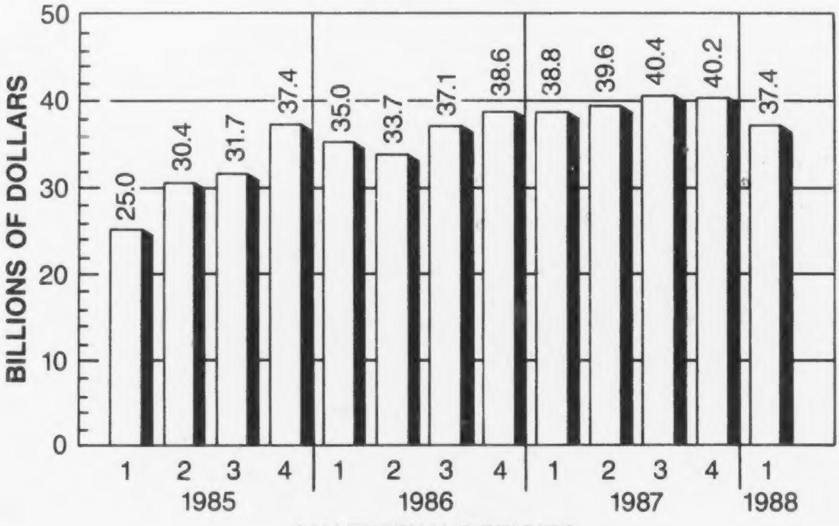
Such a rebuilding will require extensive reevaluation of existing legislation and federal regulations which inhibit and in some cases even preclude, industrial progress.

CHAPTER 2—TRADE BALANCE

ISSUES

The trade deficit continues in spite of the decline in the value of the dollar. Chart C-2A, illustrates that both exports and imports continue to rise in 1985, 1986, and 1987 with little change in the annual deficit.

CHART C-2A
TRADE DEFICIT



(Figures from U.S. Department of Commerce—Chart prepared by Committee Staff.)

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[9] Linden Blue, President, GA Technologies, LaJolla, California.

The trade deficits for 1988 are:

[In billions of dollars]

January	$11.3
February	14.4
March	11.7
April	10.3
May	[1] 10.9

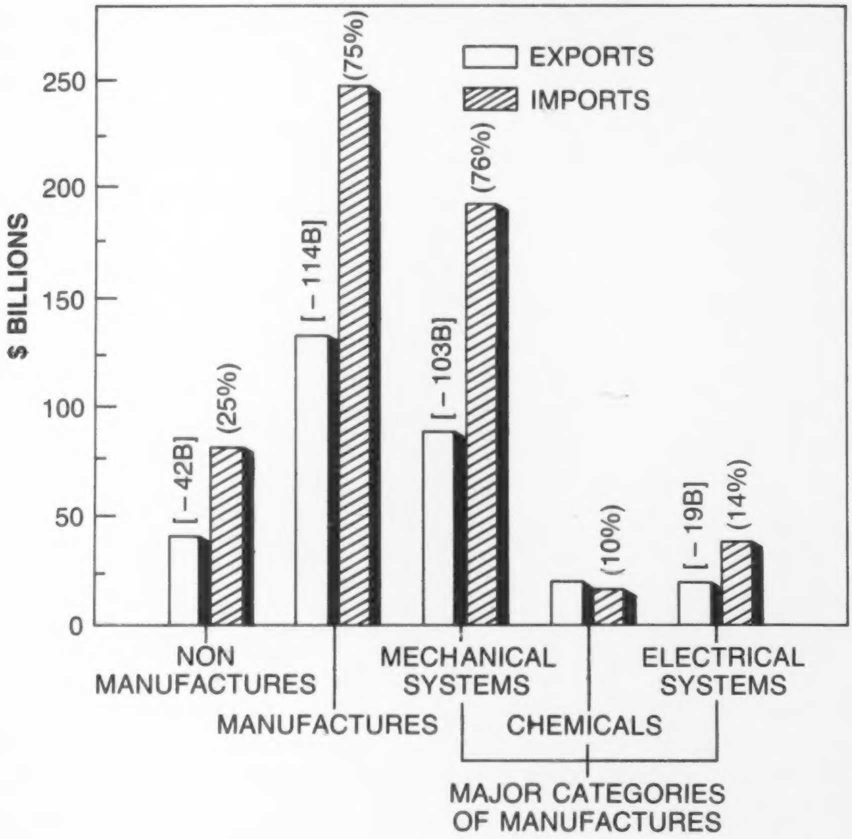
[1] Not revised as of July 27, 1988.

These figures indicate a $5 billion decrease per quarter compared to 1987. However, the United States is faced with increasing competition from other industrial nations, particularly Asiatic nations.

Industrial product manufacturing capacity is increasing on a worldwide basis. This has already led to over capacity in shipbuilding and steel. Industrial capacity in other industrial sectors can also be expected to exceed demands as other nations increase manufacturing capabilities. Furthermore, the classic solution of market expansion is limited by the economic conditions in many third world countries.

Chart C-2B illustrates the industrial sectors where the United States is not successfully competing.

CHART C-2B
1986 IMPORTS & EXPORTS OF MAJOR TRADE CATEGORIES



Source: International Trade Administration 1986, U.S. Industrial Outlook, Washington, D.C., U.S. Department of Commerce.

DISCUSSION

National economic policies play a major role in high technology development. Witnesses at Task Force hearings referred to budget and trade policies which significantly influence industrial competitiveness and therefore, the extent to which the U.S. economy can continue to support increases in the standard of living.[1]

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[1] Cyert, Richard M. and Mowery, David C., Editors. "Technology and Employment," Panel on Technology and Employment, Committee on Science, Engineering and Public Policy, National Academy Press, Washington, D.C. 1987.

Relationship Between the Trade Deficit and Federal Budget Deficit

The budget deficit, by greatly increasing foreign capital flow to the United States, made a major contribution to the high value of the dollar—which in turn was a primary mechanism initially inducing the trade deficit.[2] The large decline in the value of the dollar over the past two years led to some improvement in the trade balance. But as Lawrence notes:

> . . . the dollar's fall is not a panacea. Its decline will reduce the purchasing power of American consumers. But the day of reckoning from the excess consumption enjoyed thus far in the 1980s cannot be postponed. . . . Substantial reduction of the government deficit, and in particular, the federal budget deficit—is by far the most feasible, if politically difficult. Although macro-economists may disagree about the desirability of completely eliminating the federal deficit, there is a broad consensus that the deficit must eventually be brought down from its current $150–200 billion range to something on the order of $50 billion. There also is consensus in the policymaking community that deficit reduction should take place gradually and, if the need arises, temporarily halted or even reversed if the economy slides into a recession.[3]

Without a substantial reduction in the federal budget deficit (and a corresponding increase in budget deficits in countries with trade surpluses), some economists fear a loss of confidence by foreign investors who, until the autumn of 1986, largely financed the U.S. deficit.[4] Should that happen losses in technology development and employment in the United States would occur. If the United States is considered an unwise investment choice because of its deficits and its inability to produce what others want, then foreign investments might shift to other nations. There were some signs of lack of foreign investors confidence, but there are much stronger indications that foreign investors are purchasing U.S. assets instead.

The Trade Deficit

The trade deficit and the measures taken to achieve a balance in trade will have a major impact on technology development, manufacturing, and services in the years ahead. The following chart C-2C illustrates the change in imports between 1985 and 1987 by country of origin and shows increases in imports from most countries.

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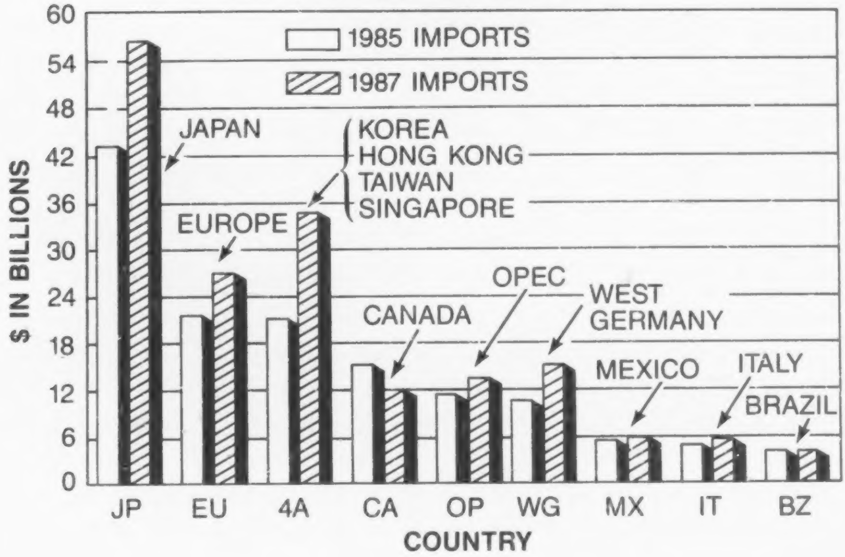
[2] Marris, Stephen, "Deficits and the Dollar Revisited," Institute for International Economics, Washington, D.C., September 1987.

[3] Hearing before the Technology Policy Task Force of the Committee on Science, Space, and Technology, 100th Congress, First Session, July 1, 1987 (No. 32), "The Effects of Technological Change on the Labor Force," pp. 54–56.

[4] Marris, Stephen, "Deficits and the Dollar Revisited", Institute for International Economics, Washington, D.C., September 1987, p. 9, and Marris, Stephen, "And What if the Dollar Overshoots?", *The Washington Post*, November 12, 1987, p. A23.

CHART C-2C
TRADE IMPORTS



(Figures from U.S. Department of Commerce—Chart prepared by Committee staff.)

Difficulties in Reducing the Trade Deficit

The magnitude of the U.S. trade deficit means that the U.S. will have to make major changes in its policies to bring trade back in balance.

> In 1986, U.S. merchandise exports "paid for" only 61 percent of U.S. imports. This is significantly worse than the position of the seven major developing-country debtor countries in 1982, when their exports covered 78 percent of their imports. . . . put starkly, eliminating the U.S. merchandise trade deficit will require either a 39 percent reduction in U.S. imports from their 1986 level, or a 64 percent increase in U.S. exports, or some combination of both.[5]

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[5] Marris, Stephen, "Deficits and the Dollar Revisited," Institute for International Economics, Washington, D.C., September 1987, pp. 7–8.

A Congressional Budget Office (CBO) study provides further evidence of the difficulty of making substantial deficit reductions. CBO's simulations show that a very rapid fall in the value of the dollar would have the greatest impact, while a recession, unless it was extremely severe, or increased foreign demand for U.S. goods, would have only a small impact. The three factors in combination would produce a modest surplus in net exports by 1990. But CBO notes:

> . . . because so much of our national debt is now held by foreigners, THE CURRENT ACCOUNT (not the trade deficit) would remain in deficit until 1992 even under the most drastic assumptions. Under a combination of these [three] changes in economic conditions, our net foreign debt would rise slowly. Without these changes . . . the debt would surge dramatically [to more than $1 trillion from the $400 billion projected by the end of this year]. [6]

Moreover, there are a number of other factors, not readily included in economic simulations, which contribute to a continuation of the trade deficit:

- The effect of the lower dollar on the price of American finished products may be less than expected because (1) most raw materials are priced in dollars and (2) U.S. manufacturers pay higher prices for components priced in foreign currencies.
- Since some currencies have not appreciated against the dollar, both American and Japanese manufacturers have increasingly moved production to countries with cheap currencies and low wages.
- Japanese and German manufacturers can reduce profit margins and still make an acceptable return because their capital costs are lower than costs in the United States.
- Many foreign producers are able to keep prices down because they did not pass along the full savings to American customers when the dollar was high.
- Many imports are marketed in the United States by American retailers or wholesalers who share foreign producers' interest in holding down the price.
- Producers also have cut costs by importing component parts for reexport from low-cost countries or by reducing profit margins. But the contribution of lower profit margins may be exaggerated. Recent research suggests that Japan's ability to main-

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[6] Statement of Edward M. Gramlich, Acting Director, Congressional Budget Office, before the Joint Economic Committee, Congress of the United States, November 5, 1987, pp. 1-11 and Farnsworth, Clyde H. "Congress Unit Pessimistic on Trade," *The New York Times*, November 6, 1987, p. D2.

tain competitive pricing may have more to do with the availability of low-cost raw materials, productivity gains, and relocation of some production offshore.[7]

The Institute for International Economics (IIE), with research institutions abroad, recently released recommendations to address the global economic crisis which has resulted from the American budget and current account deficits, the large external surpluses in Japan and the Asian NICs [newly industrialized countries], high unemployment in Europe, and debt and stagnation in many developing countries.

IIE concluded:

> The most critical single requirement is for the *United States* to free up resources to enable it to expand net exports, by holding the growth of domestic spending to 1–1½ percent below the growth of output for the next four to five years. . . . This slowing of domestic spending can best be achieved by eliminating the deficit in the federal budget.[8]

Trade Policy Objectives

Trade policy plays a major role in our society's ability to make economic gains. Consequently, the first objective is to increase production of goods within the United States. The second objective is to capture a much larger share of the U.S. market. The third objective is to increase sales in other countries. Therefore, U.S. trade policy should support these objectives. Chart C–2D indicates commodity groups where the deficits are most severe.

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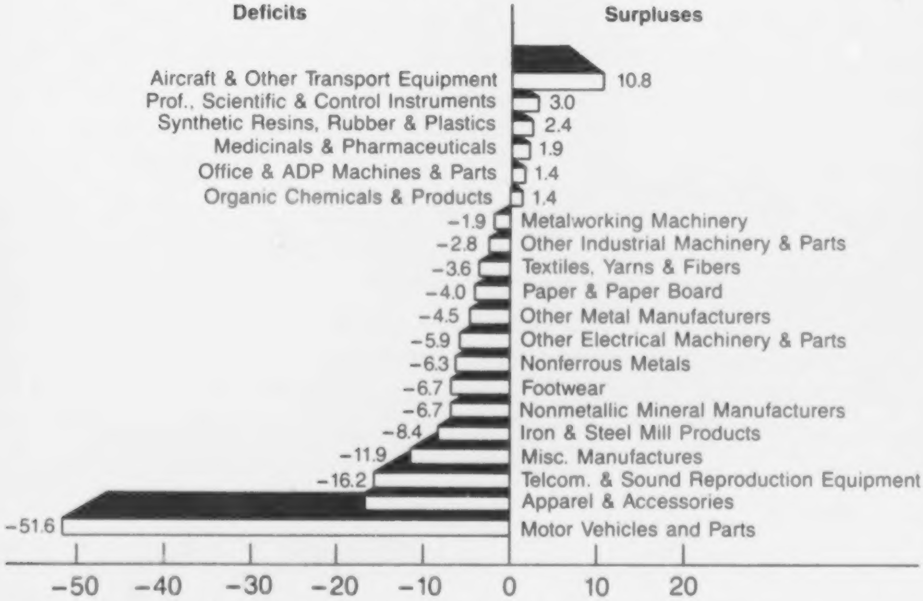
[7] Kuttner, Robert, "The Theory Gap in the Trade Gap," *The New York Times*, January 17, 1988, pp. F1, F28.

[8] Institute for International Economics, "Resolving the Global Economic Crises: After Wall Street" Washington, D.C., December 1987, pp. 1-17 and Institute for International Economics, News Release, December 16, 1987, pp. 1-7.

CHART C-2D



U.S. manufactures trade balances, by commodity groups, 1986, in billions of dollars.

International Trade Administration, Office of Trade and Analysis, U.S. Department of Commerce.

An open trade environment is generally credited with contributing to strong economic growth following World War II.[9] However, certain actions taken by competitor nations create distinct advantages for them to the detriment of U.S. export potential. Under such conditions the U.S. has little recourse other than to respond in kind to such practices. Paul Volcker, former Chairman of the Federal Reserve Board is concerned about such retaliation.

> Today, according to Volcker, the two most important things for the United States to do are to deal with the budget deficit and to avoid an outbreak of protectionism. A year after the 1929 crash, Congress passed the highly protectionist Smoot-Hawley Act, which forced other countries to retaliate by adopting excessively tight monetary policies to maintain the exchange rates of their currencies. These deflationary measures caused falling prices, economic

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[9] Auerback, Stuart, "At 40, Trade Pact Is Showing Its Age," *The Washington Post*, November 29, 1987, pp. A25–A26.

> slump and rising unemployment. Trade floundered and the great worldwide depression was on. By 1933, one out of every five American workers was unemployed.[10]

Most economists argue for the benefits of greater trade liberalization and for the importance of strengthening the GATT, the forum for multilateral trade negotiations. But, even economists who generally are opposed to increased barriers, believe some forms of protection may be warranted in certain situations. Lawrence argues for giving troubled industries "a breathing space. Give them a declining tariff, and let the chips fall where they may." [11] I.H. Destler and John S. Odell of the Institute for International Economics (IIE) conclude:

> The policy choices facing the United States and other governments can no longer be captured by simple, liberal trade-protectionist dichotomy. . . . Actions that restrict trade in the short-run can serve the interests of open trade in the longer run. Measures that reduce imports by enforcing established trade laws can be defended as offsetting (and hence discouraging) trade distortions created by foreign firms or governments. "Protectionist" steps may also, in certain cases, broaden or preserve longer run domestic political support for open trade. Such arguments can be debated. . . .[12]

In general, however, there is substantial evidence that increased protection worldwide would have adverse economic consequences. Most economists are convinced that protectionist pressures would, in the long run, be detrimental to the U.S. economy and if taken far enough could lead to worldwide depression. The experience of countries such as Great Britain indicates that the longer the domestic adjustment process is put off, the greater the damage to the economy. Indeed, it may be counterproductive for many of the workers it is intended to assist by delaying retraining and reemployment in new industries:

- Special protection as practiced in the United States rarely enables industries to regain their share of the domestic market or maintain their former level of employment without indefinite government protection, although in some cases protection has facilitated the transition to smaller and more modern firms which appear able to survive without continued protection.

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[10] Silk, Leonard, "Volcker on the Crash," *The New York Times Magazine*, November 8, 1987, p. 52.

[11] Hearing before the Technology Policy Task Force of the Committee on Science, Space, and Technology, 100th Congress, First Session, July 1, 1987 (No. 32). "The Effects of Technological Change on the Labor Force," p. 25.

[12] Destler, I.M. and Odell, John S., "Anti-Protection: Changing Forces in United States Trade Politics," Institute for International Economics, Washington, D.C., September 1987, pp. 1-7 and 125-140.

- Protection imposes "huge" costs on consumers. Consumer costs of $20,000 to $85,000 per *job-year saved* are common, with figures sometimes as high as $150,000. . . . Total costs are about $27 billion per year in Phase III of textiles and apparel, about $6.8 billion in Phase II of carbon steel, about $5.8 billion in automobiles, about $5.5 billion in dairy products and more than $100 million in most other on-going cases.
- Compared to these total costs, protection saves a "rather modest" number of jobs in most of the affected industries. Apart from textiles and apparel (640,000 jobs) and automobiles (55,000 jobs), estimates of jobs saved in other industries are "decidedly small", seldom exceeding 10,000 workers.
- Moreover, this protection often lasts "far longer than necessary for the adjustment of the *existing* labor force." It may serve only to delay worker readjustment. "The fact that costs to consumers per production job saved are so high underpins the strategy for an alternative approach that would liberally compensate departing workers for moving to new industries or early retirement."
- Protection may allocate resources to "America's least promising industries" and is likely to be inequitable with respect to these industries.[13]

In general, IIE concludes that special protection as practiced in the United States is "far from the worst system imaginable" and has the advantage of not "freezing the status quo." But a system that provided declining tariffs for a specified period of time would be superior. At the same time, policies should be designed to help workers move into internationally competitive industries. . . . "The more that labor moves into enterprises with growing national and global sales prospects, the less will its interests be served by trade protection. Certain workers will inevitably suffer when the structure of economic activity changes, as it must if firms (and nations) are to keep their competitive positions. But it would be neither fair policy nor good trade politics to make labor bear this burden alone [emphasis added]." [14]

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[13] Hufbauer, Gary Clyde and Rosen, Howard F., "Trade Policy for Troubled Industries," Institute for International Economics, Washington, D.C., March 1986, pp. 1-43 and 67-94 and Hufbauer, Gary Clyde, Berliner, Diane T. and Eliott, Kimberly Ann. "Trade Protection in the United States: 31 Case Studies," Institute for International Economics, Washington, D.C., 1986, pp. 1-29.

[14] Destler, I.M. and Odell, John S., "Anti-Protection: Changing Forces in United States Trade Policies," Institute for International Economics, Washington, D.C., September 1987, pp. 1-7, 125-140.

U.S. Trade Policy

The summary of the Conference Agreement on the Omnibus Trade and Competitiveness Act of 1988, H.R. 3, provides the U.S. trade policies which will be in effect in the years ahead. Since the Congress has acted on H.R. 3, the Task Force did not take any independent positions on the subjects covered. H.R. 3 should provide for correction of some of the deficit problems. However, other corrective actions outside the framework of H.R. 3 as discussed in this policy statement, are not any less urgent.

This policy on technology is dependent on many parts of H.R. 3. Specifically, as provided by H.R. 3, and stated in the Conference Report, the United States should take immediate action to promote exports to other nations. An increase in exports as well as a decrease in imports are essential to rebalancing trade. The establishing of U.S. missions overseas will be a positive step. The Market Development Cooperator Program and establishing export trade companies can be very effective in stimulating sales aboard.

The Task Force also notes that there will be occasions where the U.S. will have to defend itself against unfair trading practices by other nations. Accordingly, the provisions for enforcement of U.S. rights under trade agreements is encouraging. The Conference Report contained the following language:

III. Enforcement of U.S. Rights Under Trade Agreements and Response to Certain Foreign Trade Practices (Section 301 Reform)

A. Transfers determination, decision-making and implementation authority—Transfers to the U.S. Trade Representative (USTR), from the President, the authority to make determinations of whether foreign practices meet section 301 criteria. Also transfers to the USTR, subject to the direction, if any, of the President, the authorities in all cases to determine whether and what type of action is appropriate and to implement such action.

B. Makes action mandatory for foreign trade agreement violations—Requires that in cases involving foreign violations of trade agreements or other "unjustifiable" practices, the USTR must take retaliatory action in an amount equivalent in value to the foreign burden or restriction on U.S. commerce. The form of retaliation would be at his discretion, with preference given to tariff rather than quota restrictions. No retaliation would be required:

1. If the GATT Contracting Parties determine or GATT panel reports the foreign practice does not violate or deny U.S. rights or does not deny or nullify or impair U.S. trade agreement benefit.

2. If the foreign government has agreed to eliminate or phase out the practice or has agreed to a satisfactory imminent solution to remove the burden or restriction on U.S. commerce.
3. If number 1 or 2 cannot be achieved, the foreign country has agreed to provide satisfactory compensatory trade benefits.
4. If action would have an adverse impact on the U.S. economy substantially out of proportion to the benefits of action, taking into account the impact of not acting on the credibility of section 301.
5. If taking action would cause serious harm to the U.S. national security.

The bill also covers enforcement of trade agreements by providing for time limits for taking action and defines unreasonable practices.

Requiring the Office of Management and Budget to make annual assessments of the federal budget on trade balance should be helpful in refining policies to strengthen our trade position.

Technology Competitiveness Act

The following is a brief summary of provisions within the Trade Bill which recognize the role science and technology play in U.S. trade policy.

The National Bureau of Standards (NBS) is the nation's lead laboratory in the areas of measurement, calibration, and quality assurance standards. The areas of NBS' involvement range over more basic and advanced research technology, and extend into manufacturing and computer software systems. The diversity of this agency, coupled with its unique mandate to support the nation's standards and measurements, has led to enhancing NBS' role with new responsibilities for supporting U.S. industrial quality and competitiveness. This is to be accomplished by renaming NBS the National Institute of Science and Technology (NIST), and authorizing new programs and initiatives. This step provides an agency within the Federal Government for cooperation between the public and private sectors.

One of the methods the government intends to use to foster this increased cooperation is through the efforts of the Advanced Technology Program (ATP) at NIST. The ATP is authorized by the Trade Bill to encourage American companies to form joint research and development ventures to respond to industry concerns. The basis for these joint research and development ventures is found in the National Cooperative Research Act of 1984, which supported development of cooperative research and development programs such as Sematech. The ATP will be active in development of joint research and development ventures. It will be able to provide start-up funding, if appropriate, and a minority share of the ongoing costs of projects for up to five years. The ATP will also be able to participate in pooling resources to counter the activities of foreign countries.

The ATP also will permit industries to cooperate more extensively with the national laboratory system. NIST will serve as a coordinator for developing industrial access to federal laboratories through both the ATP and the Technology Trade Act.

Other initiatives authorized for NIST include the Technology Extension Services program, the Regional Centers for the Transfer of Manufacturing Technologies, and the Non-Energy Inventions Program. The Technology Extension Service permits NIST to provide technical assistance to technology extension programs operated by the states. NIST will encourage technology transfer through improved government-industry-university cooperation. The Regional Centers are intended to provide outlets to demonstrate manufacturing technology developed by NIST to small- and medium-sized firms. Overseas competitiveness and trade policies impact all size businesses, but small- and medium-sized businesses lack the necessary resources to convert extensive research and development programs into new manufacturing technologies. The Regional Centers will be initially federally-funded up to 50 percent for four years. These facilities will be used to improve the manufacturing techniques of small- and medium-sized businesses. As in the case of the Advanced Technology Program, potential grantees will be limited to U.S.-based firms, with the additional stipulation that only nonprofit institutions which demonstrate they will assist U.S.-based companies intending to use the technology in the U.S. may apply.

CONCLUSIONS

In spite of a substantial negative trade balance, there are reasons for optimism that the situation will improve. Federal and state governments are becoming more aware of the problems in the U.S. trading position. The Trade Bill contains provisions which will provide support to U.S. firms engaged in export activities. A stronger national position can only help these firms in their oversea ventures.

However, there is still a need for substantial improvements in industry performance, in exports, and in capturing larger shares of the domestic market. The government should do everything possible to provide policies which result in a "stateside" business environment that stimulates industry to produce "at home". While the need to cooperate—to a degree—with foreign governments and firms is recognized, the U.S. cannot continue to suffer a negative trade balance without appreciably lowering the living standards of most Americans.

CHAPTER 3—LONG-TERM COMMITMENTS BY INDUSTRY

ISSUES

Corporate decisions frequently result in avoiding long-term commitments. Because of major uncertainties in the global economy, these long-term commitments entail considerable risk. Short-term policy is inadequate for competing internationally.

DISCUSSION

The evolution of a new idea or concept from its inception until a product is sold in quantity is somewhere between 10 and 20 years. Implementing a manufacturing process technology can also take years.

> Five of six years were required by IBM to convert its Lexington, Kentucky, plant from traditional production methods to computer-integrated manufacturing.[1]

Corporate America, for a number of reasons, wants returns on investments to occur over a short time period. In the U.S. the shorter the investment pay back period, the more attractive the investment. Therefore, in many instances corporations do not have the incentive to carry out long-term programs or develop new facilities.

Measures that help resolve the problem of time-incompatibility between corporate investment practices and the research-development-production efforts of industry fall into one of two categories. Measures that can shorten the research-development-production period will help resolve this time-incompatiblity as will measures that lengthen the investment pay back time periods that industry can tolerate. Of course, time isn't the only relevant parameter. The higher the number of research activities oriented toward marketable products and the higher their quality, the larger the number of commercial products that will result.

Capital Investment

As illustrated in Chart C–3A, other nations, with the exception of Great Britain are making greater capital investments, as a percent of GNP, than the U.S. is making. It also shows that the U.S. has the lowest productivity growth.

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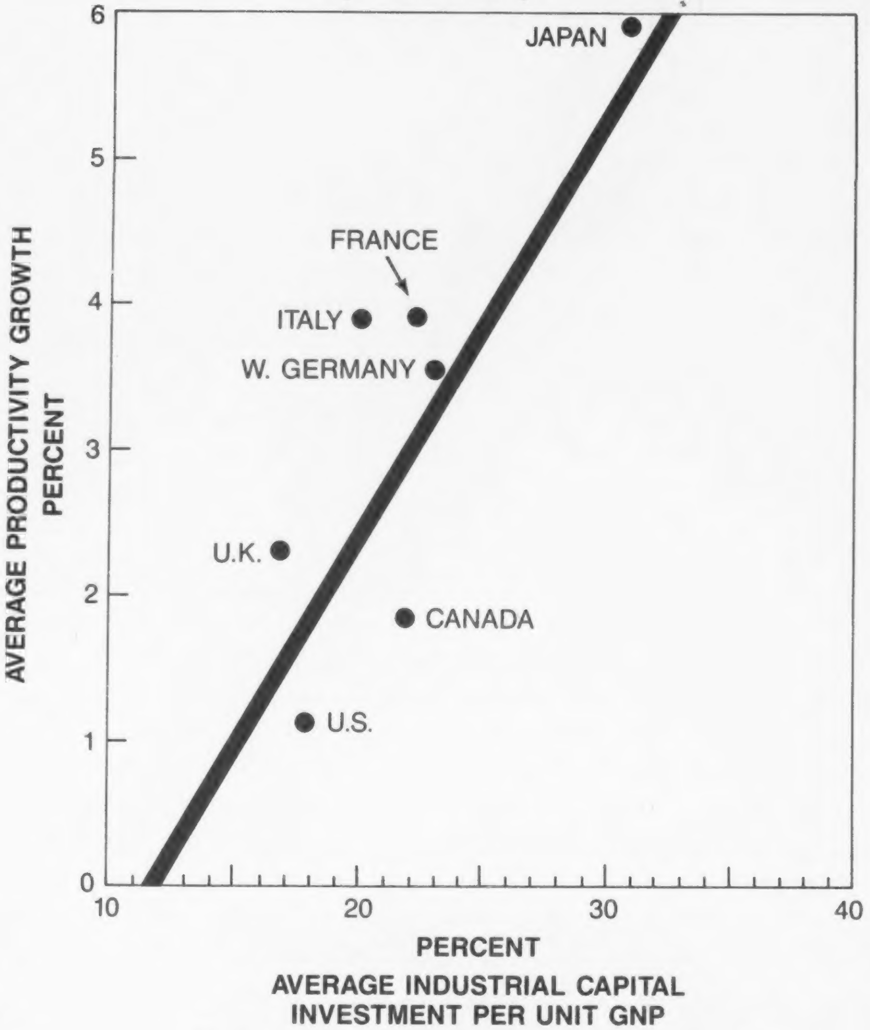
[1] Rod F. Monger, Director, Information Technology Program, Fordham University Graduate School of Business Administration, *The Impact of Corporate Financial Decisions on U.S. Technology Policy*, written for House of Representatives Technology Policy Task Force.

CHART C-3A

CORRELATION BETWEEN PRODUCTIVITY GROWTH AND INDUSTRIAL CAPITAL INVESTMENT (1960-1983)



SOURCE: U.S. DEPT. OF LABOR, BUREAU OF STATISTICS, 1984

In a highly competitive environment it is imperative that improvements be made in the commodity that is being marketed to keep ahead of the improvements being made by a competitor. Areas of improvement include not only improvements to the product being sold, but in the manufacturing and the marketing of the product, and service after it is sold. It costs money to make these improvements. Investments in: (1) development to improve products; (2) purchase of new plant and equipment to improve quality, increase yield, reduce costs, and speedup the development-manufacturing cycle; and (3) training of personnel are required in order for an industry to remain competitive.

Capital must be spent wisely. In recent years there has been a strong correlation between capital investment and economic growth.

Robert M. Solow, MIT, developed a quantitative model of economic growth in which economic growth was related to the variables capital and labor (inputs to the economy) as well as to a third variable, technology. Solow estimated that 85 percent of U.S. economic growth up to 1957 was due to increases in technology.

Dale W. Jorgenson of Harvard analyzed Japan's economic growth and concluded that their productivity growth rates were heavily influenced by their high rate of capital investment in a number of industrial sectors. He determined that the rate of Japanese investment was at least twice that of many U.S. industries. Both Germany and France, which have investment rates roughly twice the U.S. rate, have about twice the growth rate in productivity.[2]

> Solow has stated that he fears that his theory of growth, which downplayed the importance of capital, might have been carried too far, contributing to a severe underinvestment in physical capital.[3]

The importance of capital investment has become increasingly visible.

> Increased investment rates favor new technology because one never deliberately buys outdated technology. Thus capital investment stimulates technical innovation which in turn produces more capital for investment, etc.[4]

Recent evidence suggests that investment in capital not only promotes investment in manufacturing equipment and research and development, it promotes innovation and stimulates the rate of filing of industrial patents.[5] The factor that most strongly influences the rate of capital investment is the cost of capital to firms.

Factors That Inhibit Industry Investment in Research and Development

What are the factors that inhibit industry's willingness to undertake the development of a new product (including enhancing existing products) as opposed to selling the technology or having the product made in some other country for sale in the U.S.?

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[2] Ralph Landau, "U.S. Economic Growth", *Scientific American*, June, 1988.

[3] Ibid.

[4] Anthony E. Scoville, Consultant in Science and Engineering to Congressman George E. Brown, Jr.

[5] George N. Hatsopoulos, Paul R. Krugman, and Lawrence H. Summus, *The Problem of U.S. Competitiveness*.

A. Cost of Capital

Institutional investors, pension funds, etc., dominate today's capital markets. Since such investors are measured almost entirely by short-term quarter-to-quarter performance, their decisions are likewise short-term. This is one of the most visible pieces of evidence that the U.S. short-term orientation is not a characteristic limited to "Wall Street" or "Corporate Managers", but is, in fact, a characteristic in our whole society.[6]

In analyzing long-term investment returns, high costs of capital reduce a corporation's ability to assume risk and shorten the acceptable payback periods for investments. Conversely, government policies which reduce the cost of capital can increase our ability to assume risk and lengthen our investment horizon.[7]

The cost of funds plays a crucial role in determining how much a firm values future as opposed to current earnings. . . . According to George N. Hatsopoulos, Paul Krugman and Lawrence H. Summers, in 1985 American firms had a real cost of funds of 6 percent, while Japanese firms had a real cost of funds of only 1.5 percent. This means that a U.S. firm should be willing to undertake a project that lowers earnings by one dollar today and raises them by 1.2 constant dollars at some future date, only if the payoff comes in less than 3 years in the future. By contrast, a Japanese firm should be willing to sacrifice a dollar now for 1.2 dollars 12 years in the future. Thus a U.S. firm would be irresponsible not to adopt a much shorter time horizon than its Japanese counterpart.[8]

B. Rapid Paced Technology Development

The development pace in some areas of technology is, in fact, much shorter than even ten years. Microelectronics technology, in particular, can undergo major changes in one or two years. Fear of technology obsolescence can inhibit many corporations from doing research and development in rapidly moving technology areas. Of course, without research and development obsolescence is assured.

Those that choose to compete find that their development pace is driven by the evolution rate of the technology rather than by other factors.

> Today's markets are, of course, international in scale and fast developing technology dictates that competitors put

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[6] Robert M. Price, Chairman, President, and Chief Executive Office, Control Data Corporation, memorandum to Committee on Science, Space, and Technology.

[7] Boyd Gordon, Director Finance, Westinghouse Electric Corporation, Memorandum to Committee on Science, Space, and Technology from T.J. Murrin, President, Energy and Advanced Technology Group, Westinghouse Electric Corporation.

[8] George N. Hatsopoulos, Paul R. Krugman, and Lawrence H. Summers, "U.S. Competitiveness: Beyond the Trade Deficit", *Science*, July 15, 1988.

> the latest developments in their market offerings at the earliest possible date. Thus, the pace of technological change is itself a principal propelling force for short-term response and is less recognized as such by technical people. In short, global competition and technology progress are as important as immediate profit motive in placing short-term demands on the technical community.[9]

The cyclic development process that dominates industrial development requires the making of rapidly paced incremental product improvements to keep just ahead of the competition. Minimizing the period of this development cycle is necessary if industries are to remain competitive.

C. Competitor Imitation

Aside from risk concerns, technology development may be limited in the United States because potential developers believe their findings can be imitated by competitors too easily. If this is the case, potential developers may limit their development expenditures because they do not believe they will receive sufficient compensation for their efforts.[10]

The misappropriation of intellectual property—including the unauthorized use of proprietary manufacturing processes—costs American manufacturers between $8 billion and $20 billion per year. After spending $200 million to develop its potential process for manufacturing optical fibers for television communications, Corning Glass Company had their process copied by a Japanese company. Corning was unable to stop this or collect royalties.

D. Economy of Scale

Sometimes limited technology development occurs because of economies of scale. That is, the market share of a particular company may limit its ability to justify significant research and development expenditures on a new technology because it lacks the capacity to mass produce it at lower costs.

If the maximum benefits per dollar of expenditure are derived when the total expenditures on technology are large, then technology development might best be carried out enmasse by one large organization, for example, a joint venture, rather than individually by a number of small firms. The same may be true if there are similarities in the development process that are best served when developers, with different interests and areas of expertise work in close proximity. Similar gains in economy of scale may be made in manufacturing by using a manufacturing facility owned by a number of firms instead of each firm having its own facility.

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[9] Fred W. Garry, Vice President, General Electric Company, memorandum to Committee on Science, Space, and Technology.

[10] David Sappington, Evaluation of Report Concerning *Executive Summary, Technology Development*, prepared by Committee on Science, Space, and Technology. This Executive Summary contains Sappington's interpretations of comments provided by Bruce Greenwald, Ram Granadesikan, William Sharkey, and Joseph Stiglitz.

E. Fear of Technology Rejection

There are reasons other than cost and performance that influence the acceptance and use of a new technology. Emotional, legal, social and other factors can influence customer decisions. Even though a firm might be confident that it knows how to develop a new technology, customers may not be willing to make the change to an unfamiliar technology.

> It is possible that a firm might develop a "better" technology that is not compatible with the present technology; and if other users of the technology refuse to "switch" to the new technology (perhaps because of past investments in the old technology), the developer might be unsuccessful at selling his better idea.[11]

F. Corporate Practices Concentrate On Short-Term Profits

Corporate performance evaluation systems, financing practices, profit center orientation, accounting methods, and investor reporting conventions can frequently emphasize short-term corporate profit objectives. There are few incentives to stimulate management to concentrate on long-term investments. Corporate managers who are held accountable for quarterly corporate profits have difficulty getting concerned about what will happen to the corporation in 10 years. Few ambitious managers are willing to wait for the financial rewards of even a 3- to 5-year research-development-production-marketing program to demonstrate their management skills.

The long-term volatility of markets makes long-term planning exceedingly difficult; therefore, short-term measures have lower risk. For example, long-term bond yield variations over several months often exceed the entire range of bond yield variance in the 20 years after World War II. Long-term planning is a very high risk operation because of unpredictable shifts in tax policies, savings rates, international competition, global regulatory and tariff positions, government subsidies, prices of oil and raw materials, and productivity of developing countries.[12]

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[11] David Sappington, Evaluation of Report Concerning *Executive Summary, Technology Development,* prepared by Committee on Science, Space, and Technology.

[12] Personal communication, Mr. Eugene Rotberg, Executive Vice President, Merrill Lynch.

Corporate managers who promote and are successful in achieving short-term profits are frequently rewarded with lucrative bonuses. Income taxes on bonuses could be scaled to the long-term investment focus of the corporation that provided the bonus.

Accounting practices to a surprising extent dictate manufacturing decisions. Thomas E. Pryor of Computer Aided Manufacturing-International Inc. (CAM-I) has developed and is marketing a new cost accounting system for manufacturing industries.[13]

CAM-I, a nonprofit consortium, is promoting a new cost accounting system for manufacturing industries that allows industry to justify more investment through quantifiable improvements in quality, flexibility and turnaround time. Cost accounting systems modeled on the CAM-I guidelines would help U.S. companies practice the "forward accounting" approach that Japanese companies use to make financial decisions. The Japanese work toward a target cost—a certain price for a given production volume. Investments are justified on the basis of building the product to sell at the predetermined price. Many refer to this as building or designing to cost.[14]

Resistance of plant managers to improving manufacturing processes to gain quality advances is sometimes motivated by use of narrow profit centers to determine promotions and bonuses. Large scale, production testing of new processes even though they may pay off in the long run, usually reduce short-term plant output. This discourages management from implementing new processes until it is clear that the ship is sinking. Also, large companies have used profit centers as a means to promote an entrepreneurial spirit throughout the company. The lingering romantic image of the entrepreneur expanding a start-up company into a great institution may also contribute to emphasis on profit centers.

Japan's corporations tend to have a much longer range view with attention focused on end use markets. If capturing end use markets requires emphasis on gaining market share rather than short-term profit, then this is emphasized. The Japanese system results in a massive concentration of national resources on targeted markets in amounts significantly larger than is presently possible in the United States with our restrictive accounting procedures.

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[13] "The Productivity Paradox", *Business Week*, June 6, 1988.

[14] "Gearing-Up for CIM", *Information Week*, April 13, 1987.

Policies That Could Encourage Capital Investment in Research & Development

A. Government Provide Low Cost Capital

How can the financial community provide a capital foundation which takes the dynamics of the global market into account and provides the same or better financial advantages to American firms than foreign firms have?

> One approach would be for the government to provide such low cost capital under appropriate circumstances. This would leave economic decision-making centralized in the hands of business, but would provide incentives and wherewithal to undertake longer term projects.[15]

Questions on who decides which industries to fund, what criteria would be used to select industries for funding, and how much funds would be loaned are complex, but nevertheless could be resolved. Funds could be made available. For example, a federal excise tax on consumer electronics products, a luxury item, might be a way to make funds available for research and development investment in consumer electronics.

> Government financial support in the early research/development stage for new technologies . . . would certainly be beneficial. We would caution that the royalty arrangements for access to such technologies should allow sufficient returns to the private sector to undertake the still sizable risk of developing commercial applications.[16]

Congressman George E. Brown, Jr., has proposed a new banking system as an innovative method for providing more financial resources to support capital investment.

> The time has come, I believe, to establish a national capital banking system which segregates the money supply for daily commerce and short-term working capital from the money supply for long-term capital investment. These two money supplies should be managed separately according to their differing needs. Long-term monetary policy and capital supplies should be managed with special attention to investment in new industry, technological development,

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[15] Robert M. Price, Chairman, President, and Chief Executive Officer, Control Data, memorandum to Committee on Science, Space, and Technology.

[16] Boyd Gordon, Director Finance, Westinghouse Electric Corporation, memorandum to Committee on Science, Space, and Technology from T.J. Murrin, President Energy and Advanced Technology Group, Westinghouse Electric Corporation.

education and public works that may be needed at least 10 years in the future.[17]

B. Use Advanced Technology in Government Systems

Government development of the microelectronics industry in support of defense programs was done well in advance of commercial demand for microelectronics. In this way the advanced technology developed by the government pulled commercial applications rather than the demand for products pulling the technology. Early purchase of supercomputers by government laboratories helped industry provide the research and development resources to develop an industry that has flourished in the commercial marketplace.

> An analogous "incentive and wherewithal" policy could also be adopted with regard to very advanced technology. Rather than approach the technology problem on a centrally directed basis as do the Japanese, the Federal Government can stimulate development of products and services which are appropriate to its defined missions and use advanced technologies. The government in its several missions, has need of many, if not most, of the important advanced technologies.
>
> By contracting for the delivery of products to be applied to the pursuit of these missions, the government provides incentive for business to undertake to develop products which otherwise do not normally meet commercially risk/reward criteria.[18]

C. Government Encouragement of Research and Development Cooperation in Industry

Numerous initiatives could be taken to make it easier for industry to pool the research and development resources of several companies. This would avoid unnecessary duplication.

Government support of joint ventures like SEMATECH may prove beneficial, but there has not been sufficient time to measure the merits of this type of arrangement. The National Cooperative Research Act of 1984 modified existing antitrust laws to stimulate cooperation in research and development. Further antitrust legislation will be required to promote corporate sharing of flexible computer integrated manufacturing facilities and joint corporate efforts in the development of manufacturing processes.

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[17] Congressman George E. Brown, Jr., "Science, Technology and Economics in the 1980s, A View from Congress", presented at the IBM Physics Colloquium, Yorktown Heights, N.Y., September 22, 1987.

[18] Robert M. Price, Chairman, President, and Chief Executive Officer, Control Data Corporation, Memorandum to Committee on Science, Space, and Technology.

D. Reform in Accounting and Financial Systems

The problem is not simply to improve the strength and consistency of long-term measures but to encourage management and the financial community to focus on these objectives. Investors must be provided with corporate performance measures that allow effective evaluation of companies' long-term business potential. Indicators such as corporate growth, market share, and change in market share must be emphasized in order to interest investors in long-term markets. A statement of the current value of corporate assets, although difficult to measure, would be useful to the investor.

> It might be reasonable to change accounting procedures so that research and development expenditures appear as assets on a firm's books at the time an expenditure is made.[19]
>
> I approach the topic of corporate reporting with considerable trepidation, given the disaster that befell industry in trying to deal with the imposition of "inflation accounting" in which great costs have been incurred to produce no useful information. Nevertheless, if one is willing to attack the subject of GAAP reporting, then it is possible to put the emphasis in annual reports on the present value of all products and projects, short- and long-term, in a business. Appropriate display of the value of a corporation as to the sum of all its projects, present and future, has the potential of influencing even pension funds toward longer term investment.[20]

However, any changes in the current laws should take into consideration the important stockholder protection that they provide.

> The current law doesn't let companies predict even financial trends, i.e., profit and loss, growth of sales, etc. If a public company tried to sell its stock under a system of financial disclosure, other than "accepted principles of accounting", it would, in all likelihood, be indicted for fraud.[21]

Another area worthy of a close look is that of corporate dividend payments. Payment of dividends diverts cash flow from research and development and back to the investor. Therefore, dividend payments compete with research and development, particularly long-term research and development.

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[19] David Sappington, Evaluation of Report Concerning *Executive Summary, Technology Development*, prepared by Committee on Science, Space, and Technology. This Executive Summary contains Sappington's interpretations of comments provided by Bruce Greenwald, Ram Granadesikan, William Sharkey and Joseph Stiglitz.

[20] Robert M. Price, Chairman, President, and Chief Executive Officer, Control Data, memorandum to Committee on Science, Space, and Technology.

[21] Personal communication, Eugene Rotberg, Executive Vice President, Merrill Lynch.

> A major misconception is that businesses should pay dividends when they are profitable and omit dividends when they are not. But companies which are profitable often pay dividends even when the cash is difficult to obtain. Therefore any change in the practice of accounting would have to be (1) feasible and (2) coincide with appropriate changes in the law. Naturally, this has some effect on the cost of capital available for technology development. This phenomenon is fairly well understood, but dividends are still regarded as a measure of corporate profitability.[22]
>
> Of course, it is also possible that most firms now pay dividends regardless of their financial condition and future prospects to avoid being branded as "inferior firms". If this is the case, then a government policy that restricts the ability of *all firms* to pay dividends could be in the best interests of firms, investors, and the economy at large.[23]

Current accounting principles make it difficult for corporate executives to account for the advantages of such equipment as Flexible Computer Integrated Manufacturing (FCIM).

> The decision of a company to move into FCIM involves three levels: (a) a technology decision (choice of hardware, software); (b) an investment decision (e.g. accounting for greatly increased quality, reduced processing time, ability to make many different and new products, etc.); and (c) a management decision (not just of the new technology, but of the total firm which has adopted that FCIM technology).[24]

Select Programs That Have Product Potential

Until the competitive posture of the U.S. is improved, more government sponsored programs that have potential for leading to the development of products that can reduce our dependence on foreign goods, should be implemented. Programs in semiconductors, high definition T.V.s, nuclear energy, and geotechnology are a few examples of programs that have great potential for improving the competitiveness of the U.S. Other, so-called big science projects, as well as programs that emphasize U.S. prestige or scientific prowess rather than economic benefit or quality of life should be carefully and critically reviewed.

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[22] Ron F. Monger, Director, Information Technology Program, Fordham University Graduate School of Business Administration, *The Impact of Corporate Financial Decisions on U.S. Technology Policy,* written for House of Representatives Technology Policy Task Force.

[23] David Sappington, Evaluation of Report Concerning *Executive Summary, Technology Development,* prepared by Committee on Science, Space, and Technology. This Executive Sumary contains Sappington's interpretations of comments provided by Bruce Greenwald, Ram Granadesikan, William Sharkey, and Joseph Stiglitz.

[24] D. Bruce Merrifield, United States Department of Commerce, The Assistant Secretary for Productivity, Technology and Innovation, Letter to the Honorable Buddy MacKay, June 22, 1988.

CONCLUSIONS

1. The Federal Government could carefully review and consider ways in which low cost loans could be made available to industries on the basis of a system of evaluation that indicates potential for growth. These loans could support the development of new technologies and manufacturing capabilities.
2. The government could share in the financing of cooperative research and development ventures by industry and encourage these groups to make extensive use of federal and national laboratory facilities.
3. The government could commission a thorough and careful review of corporate accounting practices as well as laws that regulate these practices to determine if changes to reduce emphasis on short-term profit can be implemented.

Chapter 4—Tax Incentives

ISSUES

Tax policy influences the allocation of capital and the willingness of the private sector to take risks. The Task Reform Act of 1986 introduced many changes to our tax structure. Although current tax policy is too new to determine the full effects, it will be important to determine whether it creates greater incentives or disincentives for development than previously existed and whether it provides any incentive for industrial investment in new manufacturing or process technologies.

DISCUSSION

The Economic Recovery Tax Act of 1981 contained an incentive for investors to increase corporate risk-taking by providing for a 25% tax credit on increases in research and development expenditures. Additional legislation has modified this credit, and analyses of the effectiveness of this credit have been addressed at length in studies performed by the Congressional Research Service, GAO, and the Science Policy Task Force, among others. In addition, recent legislation has modified the Capital Gains Tax and Research and Development Limited Partnerships.

Research and Development Tax Credits

The research and development tax credit was extended by the Tax Reform Act of 1986.[1] It currently applies to qualified research expenditures paid or incurred after June 30, 1981, and before January 1, 1989. The credit is incremental. It can be claimed only for expenditures which exceed the average amount of the taxpayer's yearly qualified research expenditures in the specified base period. The specified base period is generally the preceding three years. The incremental nature of the credit is designed to reward companies which *increase* their research and development spending.

The Tax Reform Act of 1986 reduced the credit from 25 percent to 20 percent of the incremental research expenditure amount. The Act also defined what is qualified research for purposes of the credit. The rules are complex but, in general, qualified research is research involving a process of experimentation undertaken for the purpose of discovering information that is technical in nature and intended to be useful in developing a new or improved product or improvements in manufacturing processes.

The research and development tax credit has its critics and proponents, and several studies have been conducted to evaluate the effectiveness of the credit in fostering research and development.

There is a difference in opinion as to whether the research and development tax credit has stimulated investment in research and development since its enactment in 1981. Martin Baily and Robert Lawrence of the Brookings Institution believe the credit works. In the period 1980–1985 research and development spending grew 6.4%, almost twice the rate for the period 1960–1975. Baily cites the period 1980–1985 as one of very rapid growth based on a long range historical comparison.

In response to statistics showing that research and development spending grew slightly *more* rapidly between 1975–1980, pre-credit years, Baily and Lawrence claim that the true measure of industry's commitment to research and development is the ratio of research and development spending to production. That ratio grew much faster after the credit was enacted than in the five years prior to enactment of the credit.

The growth is even more impressive when the economic circumstances of the period are taken into consideration, according to Baily. From 1975 to 1980, industrial production grew 30 percent. This reflected recovery from the 1975 recession. From 1980 to 1985, production grew only 17 percent. The fact that research and development spending increased rapidly during a period of reduced production growth may be evidence the credit was effective.

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[1] The credit is also referred to as "R&E" credit for "research and experimentation."

Others finding that the credit has had a small positive effect on research and development spending include: Jane G. Gravelle of the Congressional Research Service, Kenneth Brown of the Joint Economic Committee, and Joseph Cordes of the National Academy of Sciences.

The credit also has harsh critics. Robert Eisner of Northwestern University finds that the rates of growth have been declining. He also points out that the firms that could use the credit to full advantage, i.e., those with sufficient current tax liabilities against which the credit could be claimed, invested no more than those firms which could get only partial or zero use of the credit. He also says the credit is useless in helping start up firms, since they often have no tax liabilities against which to apply the credit. In addition, Professor Eisner thinks the credit costs the Treasury too much, and instead would prefer to see direct subsidies.[2]

Philip Webre of the Congressional Budget Office also believes the credit is worthless. He has stated that the value to companies is "minuscule" and claims the upturn in research and development investment came before the passage of the credit and most likely was not influenced by the credit. Because the credit is incremental, it is weakest when we need it the most, i.e., when industrial research is declining.

Edwin Mansfield of the University of Pennsylvania, a noted expert on the effects of tax policy on research and development, has determined that the credit has only a modest effect on research and development expenditures. In addition, Mansfield presents evidence that the increase in research and development expenditures may be a result of firms reclassifying expenditures as research and development expenditures.

Critics and proponents of the credit agree on one point: The current credit can actually act as a disincentive for investment in some circumstances. It may pay a company with temporarily declining research and development expenditures, a company whose research and development is below its base, to postpone research. In this way, a company can lower its base and reap a tax benefit later on.

There are suggestions on how to correct this unintended perverse effect of the credit. Eisner suggests adjusting a company's base year by year on the basis of the growth of research and development spending in the industry as a whole. Another suggestion by Charles River Associates, Inc., who performed a study for the National Science Foundation, is to change to an "index-based structure," where a company's base would be a fixed period, such as 1981–1983. Increases in the base would be tied to inflation or some other general index.

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[2] Baily and Lawrence argue that a permanet research and development tax credit would eventually more than pay for itself by increasing the GNP.

Capital Gains Tax

The Tax Reform Act of 1986 abolished preferential treatment for capital gains. Thus, capital gains are now treated as ordinary income. This was seen by some as a trade off for cuts in the tax rates for the highest brackets [3] in an effort to create or maintain vertical equity, i.e. a fair distribution of the tax burden between income brackets.

Many observers feel that a lower rate of taxation especially for long-term capital gains is important in spurring investment in new businesses, especially high-risk high-tech ventures. Higher rates of taxation for capital gains dries up funds available for new ventures and new technologies.

When capital gains taxes are high, people tend to hold on to their assets. This is referred to as the "lock-in effect." Accordingly, capital is not available for investment in new businesses or new technologies.

Additionally, many argue that a lower rate of taxation for capital gains would enhance U.S. international competitiveness by leading to increased innovations and risk taking by U.S. businesses and investors. Virtually all of our competitors have a lower rate of taxation of capital gains than we do. Many do not tax capital gains at all.

Some observers argue that changes in the capital gains tax will bear little relationship to industry's investment decisions.

> A lower capital gains tax primarily affects how long stocks or bonds are held by investors. It has little to do with the availability of money to an industrial firm for either shorter or longer time periods. The firm already has acquired the money it will receive from the initial sale. Therefore, changing the capital gains tax law affects only the time period an investor holds the investment before selling to a new investor.[4]

It is noted, however, that firms frequently offer new blocks of stock in order to obtain capital for investment in facilities or new ventures. The higher the capital gains tax relative to taxes on other investments, the less attractive corporate stock becomes. When tax free bonds compete with highly taxed corporate stock, investor money flows away from industry and into government ventures.

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[3] The rate in the top bracket was reduced from 50 to 28%.

[4] Personal communication, Mr. Eugene Rotberg, Executive Vice President, Merrill Lynch.

The most frequently used argument against special treatment for capital gains is that it is not "fair" because it benefits "the rich". However, proponents argue that reduced capital gains taxes spur economic growth which in turn creates jobs and increases federal revenues, thereby benefiting all income brackets.

Efforts now are being made to reenact a lower rate of taxation for capital gains. Several suggestions have been made about how to tailor the tax so it is effective in enhancing productivity and encouraging longer-term risk, while getting the most "bang for the buck" and avoiding tax abuse. A graduated linear scale in which return on investments were taxed as ordinary income after 1 year and taxed at a low capital gains rate after 10 years would encourage long-term investments, reduce consumption, and promote savings.

Research and Development Limited Partnerships

An unwitting victim of tax reform was the research and development limited partnership. Under an research and development limited partnership, a sponsoring company would create a legal entity which would become the general partner. Investors become limited partners by providing capital to the general partner. The general partner would perform the research and provide the results to the sponsoring company in exchange for royalty payments. The limited partners would get the advantages of I.R.C. section 174, which allowed a taxpayer to deduct research and experimental expenditures as business expenses. In addition, the limited partners would share in royalties, which would be taxed at a lower rate as capital gains.

The research and development limited partnership functioned essentially as a tax shelter for investors. The Tax Reform Act of 1986 put major restrictions on the deduction of passive losses, thus making tax shelters less attractive. The lowering of the marginal rates and the end of preferential treatment of capital gains also served to make research and development limited partnerships less attractive to investors.

Taxes on Manufactured Goods

This report has described the need for government to provide partial funding or low cost loans to industrial consortia, particularly those with strong ties to national and federal laboratories and universities. Funding for this sponsorship could come from charging federal excise taxes on the products in the category produced by or promoted by the consortia. Of course, the same excise taxes would also be charged on imported products in this category. For example a national initiative in consumer electronics could be financed by a federal excise tax.[5]

Rosenstein also points out the relation of tax policies to trade objectives.

> Our trade competitors have been more effective in their selection of tax policies to suit their trade objectives. For example, by any measure a value added tax is considered retrogressive. However, the average European value added tax when rebated to their exporters gives the exporting manufacturer an average price advantage of 15%. Any manufacturer will assure you that a 15% price differential in the marketplace will nearly always ensure a decisive edge.[6]

Government Encourage Savings Not Consumption

Japan's citizens save at 6 to 8 times the rate of U.S. citizens.[7] The United States is currently saving only 2 percent of its national income; the average savings rate of advanced countries other than the United States is 13 percent.[8] Economists argue for the need to correct these imbalances by slowing U.S. domestic spending. They also generally agree that nations with large surpluses, like Japan, need to expand their domestic markets to increase the demand for consumer products and provide for public works projects.

> One possibility is to provide additional incentives for savings to both individuals and corporations. These incentives could be provided, for example, by reducing taxes on income from savings, or by increased taxes on consumption.[9]

Of course, increased taxes on consumption, e.g., imported oil, would require gradual implementation to avoid a serious recession. Reinstatement of the IRA, for example, might promote savings. But others point out the difficulty of projecting the outcome of specific tax policies.

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[5] Suggestion provided by Dr. David H. Staelin, Chairman, Consumer Electronics Sector Working Group, MIT Commission on Industrial Productivity.

[6] Allen B. Rosenstein, Professor of Engineering, University of California at Los Angeles, and Chairman of the Board, Pioneer Magnetics, Inc.

[7] Personal Communication, Mr. Eugene Rotberg, Executive Vice President, Merrill Lynch.

[8] G. N. Hatsopoulos, P. R. Krugman, and L. H. Summers, "The Problem of U.S. Competitiveness."

[9] Congressman George E. Brown, Jr., "Science, Technology and Economics in the 1980's, A View from Congress," presented at the IBM Physics Colloquium, Yorktown Heights, NY, September 22, 1987.

> Many techniques that are designed to increase savings merely end-up providing tax havens for money already saved and do not produce new savings. Moreover, savings go into institutional hands—insurance companies and pension funds—that are very short-term oriented.[10]

Tax Deductions for Education and Training Expenses

Tax credits for education and training expenses might also provide incentives to individuals or to industries which pay for education related to technology essential to services and manufacturing.

In testimony before the Committee, Strassman suggested these tax deductions be given high priority.

> If an employee's *knowledge* is his capital, and the basis for a major share of his earnings, then all education and training should be given the same preferential treatment as we have given traditionally to *capital*. In the industrial age societal productivity was largely determined by the easy availability of *capital*. The encouragement and protection of capital formation, whether in the form of assets or technology, has always been one of the prime objectives of government policies.
>
> In the Information Age, the *knowledge* capacity of the workforce is the basis of societal productivity gains. Capital is plentiful and becomes an easily available commodity, on a global scale. Hence, legislative policy should shift from concerns about capital to preferential treatment of every conceivable means for enhancing the *knowledge capacity* of the U.S. workforce.[11]

CONCLUSIONS

The Task Force concludes that the present tax code could be reexamined to determine applicable legislation which can further the goals of private sector technology innovation and modernization of equipment. One possibility is for the Science, Space, and Technology Committee to conduct a study of the effects of current tax provisions on research and development investment.

The Task Force believes that it is in the best interest of the U.S. Government and U.S. businesses to establish and maintain a consistent long-term tax policy. Continuous alteration of the U.S. tax code introduces uncertainty into the business sector, and can affect the allocation of capital to research and development. The fact that the present tax code is relatively new thus suggests that Congress should proceed with caution in implementing further changes. However, the Task Force believes a tax policy which stimulates the innovation, development, and manufacture of products by reducing long-term risk and providing incentives that stimulate development and export of American-made goods could be productive.

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[10] Personal Communication, Mr. Eugene Rotberg, Executive Vice President, Merrill Lynch.

[11] Hearing before the Technology Policy Task Force fo the Commitee on Science, Space, and Technology, "The Effects of Technological Change on the Labor Force", July 1, 1987.

One thing is certain; the more a company has to pay in taxes, the less it has to invest in product development and manufacturing processes. Whatever the faults of the present policy, the tax code might be modified to create a more favorable environment for research and development and plant and capital investments.

CHAPTER 5—PATENTS

ISSUE

The patent laws are designed to protect companies who invent new products and manufacturing processes. Therefore, the government should assure that private firms are afforded this privilege and protected from foreign infringement.

The government has not acted to assure that full protection against foreign infringements is occurring.

DISCUSSION

Background

A patent is an ancient practice and is the instrument which grants exclusive rights as a means of promoting innovation. The Greek historian Phylarchus (3rd Century B.C.) recorded a law of the Sybarites giving confectioners or cooks who invented any "peculiar and excellent dish" exclusive rights to produce it for one year "in order that the others be induced to labor at excelling in such pursuits." [1] Reid Adler explains that the "doges of Venice and Kings of England granted monoplies (from the Greek monopolion, right of exclusive sale) to inventors as an inducement for them to trade new articles that would be of benefit to society." [2]

The Task Force believes that government policies should be designed to provide incentives for industry to develop and commercialize technology. Patent policy is one important means of providing this incentive. The competitiveness of American industry can be strengthened by providing more effective legal protection for American inventions. Strong and enforceable patent laws encourage companies to invest time and money in research and development, when they believe there is potential for profit. The patent system protects incentives for invention and innovation. While U.S. patent law is generally effective, it does not go far enough to protect the intellectual property rights of American firms.

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[1] C.D. Yonge, *Translation, the Deiphosophists of Athenaeus*, (London: Bohn, 1854), Vol. 3, p. 835.

[2] Adler G. Reid, "Biotechnology as an Intellectual Property", *Science*, April 27, 1984, Vol. 224, p. 358.

The patent system encourages inventions that advance our technology and enrich our knowledge. Disclosure of how the invention actually functions, made by the Patent Trademark Office upon patent issue, "encourages competitors to design around or improve a patented invention, further advancing technology." [3] The patent system also provides incentives to risk an attempt to commercialize an invention adding to society's benefits as Professor Levin explains:

> By conferring property rights that restrict temporarily the wide use of new knowledge, the patent system is supposed to create the incentive to engage in inventive activity and to undertake the costly investment typically required to reduce an invention to practice.[4]

The U.S. Chamber of Commerce finds that "an effective patent system stimulates international trade by allowing the patent owner to protect export markets and by encouraging transfer of technology through licensing and sale of patent rights." [5] Attorney Michael H. Stein, representing Corning Glassworks explains how "meaningful enforcement of U.S. patent, maskwork, and other intellectual property laws is extremely important to Corning and other high technology U.S. corporations, because it goes to the heart of their ability not only to recoup the hundreds of millions of dollars already invested, but to their ability to continue to make the huge investments necessary for continued participation in these markets in the future." [6] Strong, effective patent protection is essential for the competitiveness of American industries.

Patents for Manufacturing Processes

Many firms in the United States have spent millions of dollars developing innovative processes to make certain products. Under current law, process patent owners in the United States are protected against those who copy their process and use it to produce goods in the United States. However, this protection does not extend to those who copy the process and manufacture outside of the United States. It also doesn't prevent those infringing products from being imported into the United States. Most of our major trading competitors, including Japan, West Germany, France, and the United Kingdom have process patent protection in their own patent laws. As Senator DeConcini says, "Our laws must enable U.S. companies to protect themselves from foreign manufacturers which steal American owned technology and then use American innovations to compete with U.S. manufactured products." [7] A patent owner has one option to protect his patented process: to seek relief from the International Trade Commission (ITC) for violation of section 337 of the Tariff Act of 1930. The patentee can seek a cease and desist order against a particular firm or an exclusion order that would bar the products from entering the United States. This remedy, however, is inadequate because damages cannot be awarded to compensate for past injuries, and under present law, it is extremely difficult to obtain an injunction through section 337 (discussed below).

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[3] Ibid., p. 358.

[4] Richard Levin, "A New Look at the Patent System", *AEA Papers and Proceedings*, May 1986, Vol. 76, p. 199.

[5] U.S. Chamber of Commerce, *Guidelines for Standards for the Protection and Enforcement of Patents*, April 29, 1987.

[6] Testimony of Michael H. Stein, appearing at a hearing, "Intellectual Property and Trade", on behalf of Corning Glassworks before the Subcommittee on Courts, Civil Liberties and the Administration of Justice of the House Judiciary Committee, April 23, 1986, p. 242.

Patent owners should be able to exclude not only manufacturers, but also sellers and users of the infringing products, including importers, distributors, and retailers. They should be held accountable for infringement, after proper notice has been given, if patents are to be effectively enforced. Finally, patents should be enforceable without excessive expense or burden for the patent owner. Opponents of process patent legislation, such as the Generic Pharmaceutical Association, argue that U.S. consumers benefit by the importation and use of cheaper imports. Ultimately, however, the United States is damaged by lack of process patent protection because of the loss of needed revenue by American industries as well as the loss of jobs for American workers. As explained by the U.S. Chamber of Commerce, "In the long run, consumers benefit from effective patent protection. They reap the benefits of a strong economy and enjoy the higher standard of living made possible by more advanced and varied consumer products."

Process patents are critical to certain industries, such as chemicals and pharmaceuticals, which often make old, nonpatentable products, in more modern and efficient ways, as well as to biotechnology and telecommunications firms. In testimony to the House Judiciary Committee's Subcommittee on Courts, Civil Liberties, and the Administration of Justice, Thomas Kiley, Vice-President of Genentech described his company's breakthrough in the production of Vitamin C.[8] Genentech was able to compress five steps in the process into just one step, providing a more efficient and economical method for the production of Vitamin C, but the process patent cannot be enforced to prevent infringing imports of Vitamin C. He questions whether American industry should "invest in domestic capacity for the utilization of this new process or can it be expected that our markets will be flooded with products made overseas by the use of that process." Roy Massengill, General Patent Counsel, Allied Signal, Inc. agrees, explaining in his testimony how American firms and workers are being harmed. He discusses the costs of ITC proceedings that discourage smaller companies from ever making a claim.[9]

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[7] Statement of Senator Dennis DeConcini (D-AZ), "Process Patent Legislation", Hearing before the Subcommittee on Patent, Copyrights, and Trademarks, Senate Judiciary Committee, April 22, 1987.

Section 337—The Tariff Act of 1930

Section 337 of the Tariff Act of 1930 authorizes the U.S. International Trade Commission (ITC) to issue exclusion orders against importers when unfair trading practices are involved. It was originally intended as a trade statute, but the majority of cases that arise under section 337 relate to patent infringement. Because of its original purpose, "the provision of relief is contingent on the firms' meeting certain economic tests, normally not associated with the protection of intellectual property rights. These tests require complainants to demonstrate that (1) there is a domestic industry, (2) it is efficiently and economically operated, and (3) the unfair acts of respondents have the effect or tendency to destroy or substantially injure that industry. Because of these tests, some holders of valid and enforceable intellectual property rights that are being infringed by imports are denied access to section 337 relief." [10] The General Accounting Office Report: International Trade, Strengthening Trade Law Protection of Intellectual Property Rights (August, 1986) finds four areas of legislative changes that are needed for section 337.

- Increase access to section 337 relief by eliminating or redefining statutory criteria for obtaining relief.
- Direct the ITC to speed relief when complainants need expedited government assistance and when no respondents participate in the proceedings.

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[8] Testimony of Thomas Kiley, Vice-President and General Counsel, Genentech. Hearing before the Subcommittee on Courts, Civil Liberties, and the Administration of Justice, April 23, 1986, p. 77.

[9] Ibid., p. 92, Roy Massengill, General Patent Counsel, Allied Signal, Inc.

[10] U.S. General Accounting Office Report to Selected Congressional Subcommittees, *International Trade: Strengthening Trade Law Protection of Intellectual Property Rights*, August 1986, p. 3.

- Clarify the ITC's authority to issue both exclusion orders and cease and desist orders to remedy the same unfair trade practice.
- Strengthen the Customs Service's ability to enforce section 337 exclusion orders.

Patent Term Restoration

In 1984, Congress passed the Patent Term Restoration Act which returned the years lost during pre-market regulation to the 17 year patent term of new pharmaceuticals, medical devices, and food additives. Once a patent is issued, a patented pharmaceutical, for example, must still be reviewed by the Food and Drug Administration, before its clinical use is authorized. Genetically engineered pesticides must be subjected to review by the Environmental Protection Agency before use. These regulatory activities can take as much as five years which becomes time lost on the patent term. The 1984 Act would restore patent life up to five years. The Act provides for an extension in effective patent life equal to the sum of the application review time by the FDA plus one-half the clinical testing time. The legislation, however, is limited to certain areas. Current patent legislation would restore those lost years to the patent term for animal drugs and agricultural and industrial chemicals. Dr. Jack Early, President of the National Agricultural Chemicals Association, in testimony before the Subcommittee on Courts, Civil Liberties, and the Administration of Justice estimated that the average time for completion of regulatory review for agrochemical is five to seven years.[11] On the average, he explained it takes $40 million to bring a new agrochemical from discovery to market. If a new manufacturing plant is required, it will need an additional expenditure of $40 to $70 million. "When expense of this size is confronted within the context of a six-year erosion in the life of the patent, it becomes difficult to achieve a suitable financial return on these investments." Commissioner Donald Quigg of the Patent and Trademark Office agrees in his testimomy to the Senate Subcommittee on Patents, Copyrights and Trademarks:

> Because a shortened effective patent term lessens the incentive for industry to continue making large commitments toward research and development, we need to move to insure that those incentives are restored. Effective

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[11] Dr. Jack Early, President, National Agricultural Chemicals Association. Hearings on Agricultural Patent and Term Restoration before the Subcommittee on Courts, Civil Liberties and the Administration of Justice, July 17, 1986, p. 33.

patent protection is a necessary prerequisite to chemical research, given the enormous costs and risks involved.[12]

The Ownership Of Inventions Resulting From Federally Funded Research and Development

Another patent area that has come under criticism as an impediment to commercialization has been government policy to retain patent rights to inventions resulting from federally funded research and development. Although, the government holds title to more than 28,000 inventions, only 10% of these are used, compared to 40-65% of private-owned patents.[13] Admittedly, many of these patents cover items that have little commercial value. "While the Federal Government directly funds basic research and that applied research necessary to meet the mission requirements of the federal departments and agencies, commercialization is the responsibility of the private sector." [14] On the other hand without title to an invention, a company will not invest the personnel, time, or money necessary to develop a product. P.L. 96-517, known as the Bayh-Dole Act of 1980 gave universities and other nonprofit organizations and small businesses the option to retain title to federally funded inventions that they develop. A GAO survey indicated that P.L. 96-517 has had a "significant positive impact on research and innovation efforts." [15] There have since been proposals to extend the act to cover all large businesses. These proposals should be taken seriously as they can have a significant impact on product development as noted in Section A, Chapters 1 and 2.

Since the Bayh-Dole Act was passed, the government has taken additional steps to extend title rights. On February 18, 1983, President Reagan issued a memorandum on government patent policy to agencies stating that title rights should be extended to all large businesses for the federally funded inventions that they develop. P.L. 98-620 (November 8, 1984) eased restrictions on small-businesses and nonprofit institutions to retain these rights. Also under this law, private companies, regardless of size, are able to obtain exclusive licenses for the life of the patent. Prior restrictions allowed large corporations exclusive license for only five years. The law also permits Government-Owned, Contractor-Operated (GOCO) facilities operated by small businesses, universities or other nonprofit institutions to retain title to inventions made in the laboratory. Laboratories operated by large companies are not included in this provision. John Soderstrom of Oak Ridge Laboratory believes that "the provisions should provide a significant incentive to establish active technology transfer and patent programs that may lead to the commercialization of the research conducted in national laboratories." [16] Individual federal agencies, such as the Department of Energy, have extended the provisions to some for-profit contractors through waivers. Amendments to the Stevenson-Wydler Technology Innovation Act (P.L. 99-502) allow companies, regardless of size, to retain title to inventions resulting from research performed under cooperative agreement with federal laboratories. The Federal Government retains a royalty free license to use these patents. New legislation should clarify whether all large corporations will be able to retain title to inventions made through federally funded research, provided that the inventions are commercialized. As William Carpenter, Vice-President Martin Marietta Energy Systems says in testimony to the House Committee on Science, Space, and Technology: "Like any other performing contractor, the for-profit contractor (particularly the GOCOs) should be given technology ownership for commercial needs because the originating firms know more about the technology than any other organization. Thus, they are better positioned and perhaps more motivated to adapt it to other uses." [17] A uniform, consistent patent policy should be instituted to promote technology transfer.

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[12] Donald Quigg, Acting Commissioner of the Patent and Trademark Office. Hearing on Agricultural Patent Reform Act before the Subcommittee on Patents, Copyrights, and Trademarks, September 10, 1985, p. 27.

[13] Wendy Schact, Congressional Research Service, *Industrial Innovation: Debate Over Government Policy*, May 15, 1987, p. 9.

[14] A Study Prepared for the Joint Economic Committee: *The U.S Climate for Entrepreneurship and Innovation*, December 28, 1984, p. 43.

[15] GAO Report to the Subcommittee on Courts, Civil Liberties, and the Administration of Justice, *Patent Policy: Recent Changes in Federal Law Considered Beneficial*, April 1987, p. 16.

Through these efforts, technologies with commercial applications are more likely to be brought by private industries to the market. New legislation should be enacted that will encourage increased industry cooperation with universities and national laboratories. The laboratories should be allowed to deal directly with industry to make technology transfer as simple and direct as posible.

> The value of intellectual property is often perishable with time. Inventions developed . . . on the leading edge of technology . . . are highly susceptible to rapid change. The ability to make timely decisions is important in order to respond quickly to industrial requests for licenses. Delays in assigning patents can often result in missed opportunities to successfully transfer the technology either because

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[16] E. Jonathan Soderstrom and Bruce M. Winchell, "Patent Policy Changes Stimulating Commercial Application of Federal Research and Development", *Research Management*, May-June 1986, p. 36.

[17] William Carpenter, Vice-President, Martin Marietta Energy Systems, Hearings on the Role of Science and Technology in Competitiveness by the Subcommittee on Science, Research and Technology, April 30, 1987.

> alternative technologies are developed, the market opportunity to capitalize on the project passes, or the company grows frustrated and loses interest in the technology.[18]

The Federal Government should create a simple structural mechanism to encourage the transfer of technology, developed by public funds or by national laboratories, to the marketplace. "Finding ways to improve the flow of technology and expertise from federal laboratories to the commercial sector is an important component of a comprehensive strategy to improve the Nation's climate for entrepreneurship and innovation." [19]

The Patent Law Amendments Act of 1984, P.L. 98–622 established the Statutory Invention Registration (SIR) procedures. "SIRs were designated to provide inventors with a less time-consuming and less expensive alternative to a patent. A SIR is intended to provide the holder the defensive rights that a patent provides to prevent others from patenting the invention, but it does not permit the holder to exclude others from making, using, or selling the invention." [20] A GAO report states that "filing a SIR has two advantages: (1) the Patent and Trademark Office recognizes the SIR as of the date that the application is filed while publication of an article could be delayed by the journal's review process and (2) a SIR applicant can participate in a Patent and Trademark Office interference proceeding if a subsequent inventor applies for a patent, while an inventor who relies on public disclosure is not allowed to participate." [21] Senator Charles Mathias said the new procedures "was especially well suited for inventors who worked for the government, because in many cases all they needed was protection from suits for infringement. They are not interested in exclusive rights to use the patent." [22] Congress intended that SIRs would be actively utilized, but federal agencies have used them infrequently. It seems that most universities and small businesses are unaware of the procedure.

First To File vs. First To Invent Systems

When determining who is entitled to hold the patent rights to an invention, the U.S. Patent and Trademark Office always grants title to the first to invent. Every other country, with the exception of Canada and the Philippines uses the first to file system. Canada has already indicated that it will move to first to file, which is a patent system that eliminates the uncertainty in deciding who actually should receive title rights. The first to invent system was established in the interest of equity and allows inventors to delay filing. However, it is important that inventors file quickly so that the product can be more rapidly commercialized and the technical information publicly disclosed. In international markets, U.S. inventors already have to file promptly because of the different system and in general find it to be a more practical method. The U.S. Government has suggested that it would like to move to the first to file system, but only if other countries will grant certain concessions related to intellectual property rights during the upcoming General Agreement on Tariffs and Trade (GATT) Rounds.

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[18] Ibid.

[19] *The U.S. Climate for Entrepreneurship and Innovation*, p. 51.

[20] AGO Report, *Patent Policy: Recent Changes in Federal Law Considered Beneficial*, p. 10.

[21] Ibid., p. 11.

[22] 1984 CQ Almanac, p. 261.

Protecting Patent Rights Abroad

It is important that the U.S. Government pressure other countries to protect patent rights of U.S. inventors. American firms lose billions of dollars in sales each year as a result of foreign infringement of their patent rights. Often, new technologies in areas such as computer software, pharmaceuticals, biotechnology and chemicals are not covered under the patent laws of some countries. The Administration's international efforts to improve protection of U.S. intellectual property rights have intensified because of the increasing threat posed to American industry by infringing firms. On April 7, 1986, the office of the U.S. Trade Representative issued a policy statement outlining the underlying premises of the Administration's position: (1) All countries' economic growth and international competitiveness can be enhanced by strong domestic intellectual property protection; (2) when countries do not provide strong protection of intellectual property rights, and when an effective system of international enforcement does not exist, substantial distortions in international production and trade result; (3) the United States has a very substantial stake in a healthy system of international trade and strong protection of intellectual property.[23]

In a hearing before the Senate Subcommittee on Foreign Commerce and Tourism, Donald J. Quigg, Assistant Secretary and Commissioner of Patents and Trademarks, explained certain differences between U.S. and Japanese patent laws.

> Japan has a system of both pre- and post-grant opposition. Post-grant opposition is an element of EPO [European Patent Office] practice and is similar to our reexamination procedure. Japan's pre-grant opposition procedures are

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[23] Emory Simon, Report for the Office of the U.S. Trade Representative, *Administration Policy and Actions on Intellectual Property Protection Abroad*, June 1987, p. 5.

> skillfully used by Japanese industry to slow down the issuance of competitor's patents.[24]

In practice, this pre-grant opposition provision together with the delays in processing of applications by the Japanese Patent Office (JPO) (seven years in Japan compared to two years in the U.S.) and the release of information about the patent application in Japan (in the U.S., the information is kept secret during the application period) affords Japanese firms ample opportunity to capture a share of the invention made by a U.S. manufacturer. Frequently, the U.S. firm is then forced to cross-license its technology.[25]

A 1986 staff report by the Committee on Energy and Commerce Subcommittee on Oversight and Investigations revealed that "according to the manager of a major American drug manufacturer with operations in Thailand, a generic look-alike of a new U.S. or European drug is available from Thai manufacturers in as little as two weeks after it is introduced to the Thai market." [26] The report also detailed a relevant case in Taiwan involving Monsanto's best-selling herbicide product, Roundup:

> Despite the fact that Monsanto has valid patents in Taiwan for both the composition of ingredients in Roundup and the process by which the ingredients are assembled, a Taiwanese company, Shin Dar, has been allowed to infringe the patents since 1980. Shin Dar sells the infringing herbicide under the name of glyphosate, which is the active ingredient in Roundup . . . According to the American Institute in Taiwan, Monsanto's 1985 losses in third markets to Shin Dar could be as much as $1.6 billion. Monsanto's repeated efforts to get the Taiwanese authorities to stop Shin Dar's infringement have been unsuccessful. Recently, Monsanto and Shin Dar have reportedly reached an agreement whereby Shin Dar will produce Roundup for Monsanto.[27]

This case clearly illustrates how inadequate patent protection by other countries hurts American firms and can force them into unintended agreements they should not have to make. An American pharmaceutical firm, Pfizer reports that in 1984 it sold over $47 million worth of its 12 leading products abroad. Pirates sold about $42 million of these same products in 12 developing countries.[28] Our potential markets are being stolen abroad by pirates who do not have to spend the millions of dollars in research and development on a product. In 1985, the Commerce Department found major problem areas in patent protection in Taiwan, South Korea, Singapore, Thailand, Indonesia, Philippines, Mexico, Brazil, and India.[29]

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[24] Formal statement of Donald J. Quigg, hearing before the Senate Subcommittee on Foreign Commerce and Tourism, Committee on Commerce, Science and Transportation; June 24, 1988.

[25] Prepared testimony of Joseph A. Massey before the Subcommittee on Foreign Commerce and Tourism, Committee on Commerce and Transportation, U.S. Senate, June 24, 1988.

[26] *Unfair Foreign Trade Practices: Selected Problems in Five Far East Countries*, Staff Report by the Subcommittee on Oversight and Investigations of the House Committee on Energy and Commerce, June 1986, p. 10.

[27] Ibid., p. 19.

CONCLUSIONS

Patents based on joint industry/government laboratory programs could be granted to U.S. owned firms in return for royalty payments as discussed in Section B. This privilege could be extended to large profit-making corporations as well as smaller firms.

Patent laws for manufacturing processes need to be strengthened to protect U.S. patent holders against imports manufactured overseas using their process. In such cases, when a process has been patented in the U.S., goods manufactured outside the United States by that process should be prevented from entering the country.

Licensing of products for manufacturing by foreign producers could be reviewed by government to assure that this practice is not compromising U.S. competitiveness.

The U.S. Patent and Trademark Office (USPTO) should be supported in its efforts in Trilateral Cooperation with the European Patent Office (EPO) and the Japanese Patent Office (JPO). In this regard, work should be directed toward obtaining equal protection for American inventors in the EPO and JPO. This equality could be enhanced if the JPO had a staff, sufficient in number, to process patents in a reasonable time period.

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[28] Unfair Foreign Trade Practices, Part III, Hearings before the Subcommittee on Oversight and Investigations and the Special Subcommittee on U.S. Pacific-Rim Trade of the House Energy and Commerce Committee, April 16, 1986, p. 24.

[29] Eileen Hill, "Intellectual Property Rights", *Business America*, March 18, 1985, p. 8.

SECTION D—HUMAN RESOURCES

INTRODUCTION

Our most important resource is our citizens. This section considers how we can educate people to be more productive in a high technology society as well as the social costs of industrial transition.

There are approximately 114 million people in the civilian labor force out of a total population of 244 million. There have been dramatic changes in the kinds of employment in the U.S. workforce as well as corresponding changes in skill requirements. From the point of view of employment, the United States, along with other industrialized nations, has shifted from an agricultural society, to a manufacturing society, and more recently to a service society. The nation has been particularly successful in providing employment for 47 percent of the population in 1987 compared to 39 percent in 1960.

But the need for a larger number of highly skilled people in the future workforce is clear. This section points out increasing requirements for technical expertise, particularly in the engineering and manufacturing disciplines. It also discusses the education of our young people, in subjects such as mathematics and science, both to increase their skills in the workplace and to help them participate more wisely in a society confronted by new medical treatments, different energy systems, new concepts of transportation, and changing life-styles.

The demographics in the United States are changing. It is estimated that between 1985 and 2000, up to 85 percent of entrants to the workforce will be women, minorities, and the handicapped.[1] At the same time, it is estimated for the U.S. to retain its strength in technical fields, it is imperative that women, minorities, and the handicapped be afforded every opportunity to pursue careers in these areas. Furthermore, educational institutions and professional societies need to establish programs to attract members of these groups into the engineering disciplines.

The Task Force also recognizes a serious problem in educating the youth in urban areas. Without effective changes in the conditions in the urban schools, a significant proportion of our population may lack the skills needed to compete for middle-income jobs in high-technology and information industries. Indeed, "America continues to face the very real possibility of the two separate societies envisioned by the Kerner Commission two decades ago." [2] Compounding the problem is the recent decline in college enrollments of low-income students particularly among blacks.

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[1] Department of Labor, *Workforce 2000*, 1987, pp. xx–xxi.

Finally, the Human Resources section summarizes a broad range of proposals addressed to industrial transition, technological change, and labor displacement. The workforce will be faced with an increasing need to prepare for career changes by participating in continuing education. The chapter considers programs which would enable workers to move from one type of employment to another. Another set of proposals is focused more narrowly on programs designed to provide transitional assistance to workers adversely affected by industrial change. These proposals would adjust the focus of education, retrain displaced workers, or in some manner cope with the pressures on American workers, either by addressing industrial declines and shifts directly or by channeling workers' productive energies into areas where they can make a contribution.

The purpose is to examine these issues from different perspectives rather than to propose definitive "solutions". The discussion draws on testimony and a range of research and policy analyses. It represents different constituencies and different theoretical approaches. It sometimes presents different views about how to address problems or, indeed, where to focus attention. But it also reflects a shared understanding of the importance of increasing the technological expertise of American engineers and production workers and a strong commitment to developing public policies to alleviate adverse effects on workers.

CHAPTER 1—TECHNICAL EXPERTISE

ISSUE

The United States retains a leadership position in basic research and technological innovation, but gives less priority than some of its trading partners to technology applications, product quality, and marketing. It is not the quality of the basic research but the transition to product development that creates the problem. In order to improve products and manufacturing processes, the United States needs to place more emphasis on technical expertise directly related to industrial needs.

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[2] The Carnegie Foundation for the Advancement of Teaching, Board of Trustees, "An Imperiled Generation: Saving Urban Schools", Princeton, New Jersey, 1988, p. xi.

DISCUSSION

Weaknesses in American manufacturing have become more visible in recent years as foreign competition increases, although many American firms are taking steps to improve manufacturing and increase market access.

The Task Force concludes that the greatest challenge with respect to increasing sales in the global market lies in the education and training of our people. Particular emphasis is needed in the disciplines and trades that contribute directly to finished products such as manufactured products, construction projects, and efficient essential services which support the economy.

From a technology point of view, the goal is to increase the proficiency of U.S. engineers and production workers so that: (1) the nation can be on the leading edge of technology over the long term and master the practice of making incremental rapid improvements in technology; and (2) basic research discoveries can be effectively converted into commercial products.

> All over America there is growing worry that the Japanese are running off with our technology . . . [But] the underlying predicament is not that the Japanese are exploiting our discoveries but that we can't turn basic inventions into new products nearly as fast or as well as they can. Rather than guard our technological breakthroughs, we should learn how better to make use of breakthroughs whenever they occur around the globe. . . . What's crucial is the extent of American engineers' and production workers' technological experience—their cumulative insights into how technologies work and how they can be adapted and improved—for only prior experience enables one to absorb the new technological learning and translate it into new experience. . . . What needs to be stockpiled is not gadgets or things but experience and competence. As long as our engineers and production workers have accumulated experience in the technologies on which the Japanese gadgets are based, they can easily contrive replacements. Indeed, because high technologies evolve so quickly, both our military security and our commercial competitiveness turn on how quickly we can transform emerging technologies into the next generation of gadgets.[3]

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[3] Reich, Robert B., "The Rise of Techno-Nationalism", *The Atlantic Monthly*, May 1987, pp. 63-69.

Engineering Education

Some redirection in the focus of engineering education can assist in this process. It is important to train engineering students to design and implement production processes by giving them more experience in problem solving, systems engineering, and quality control. Joseph Froomkin, President, Joseph Froomkin, Inc., describes the problem:

> . . . newly-graduated engineers who work in production are not trained to deal with the problems encountered routinely on the factory floor. Many never learn how to handle them. A further stumbling block on the way to improving production processes in America industry is the trend for many engineers to be located far away from the shop floor. They work at data processing terminals, scheduling production and checking on its progress. They are not exposed to the problems of workers and not challenged to do the small marginal improvements which rationalize and cut costs in making a product. But despite all its shortcomings, the American organization of engineering staffs is not without its advantages: it enables companies to adopt some productive innovative techniques more rapidly. . . . Our engineers have more experience using computers than those in foreign countries and are far ahead of the rest of the world in designing products with the aid of computer.[4]

Allen B. Rosenstein also commented:

> Although engineering students are brighter than ever, the engineering colleges are no longer staffed or prepared to teach the type of engineering needed for a competitive society. The engineering schools of the land grant tradition have been replaced with schools of occasionally applied science. In the research university, professors are rewarded for their research prowess.[5]

The importance of training engineers in manufacturing technology has received wide support. For example, the American Society for Engineering Education recommends that more advanced degree programs should be directed toward the "practice of engineering" to complement the currently available research programs.[6] The engineering research centers funded by the National Science Foundation (NSF) are intended to increase collaborative research between universities and industry so that research findings will be more directly relevant to industrial needs.[7] The Task Force also urges the National Science Foundation to continue with its activities in carrying out the Science and Engineering Equal Opportunities Act [U.S.C. 1985]. Among their other benefits these activities can help increase the participation of engineers in fields associated with manufacturing and product development.

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[4] Froomkin, Joseph, *New Initiatives to Restore Competitiveness*, prepared for the Technology Policy Task Force of the Committee on Science, Space, and Technology, 100th Congress, First Session, August 6, 1987, pp. 1–10.

[5] Letter to Ronald E. Williams, Study Director, Technology Policy Task Force, from Allen B. Rosenstein, Chairman of the Board of Pioneer Magnetics, Inc., Santa Monica, CA, June 1, 1988.

A thorough knowledge of the discipline is essential, but so is practical experience gained in the field, the design room, and the factory. This practical experience is a responsibility of industry, not the universities or government. Keikou Terui, Ministry of International Trade and Industry, Chiyodaku, Tokyo, informed the Task Force that upon graduation, the best engineers join the large Japanese manufacturing firms where they then begin training for their careers and eventually move into key management positions.

But few U.S. firms reward engineers in manufacturing positions with salary levels consistent with those of design engineers and engineering managers. Don Hammon, formerly with Hewlett-Packard, told the Task Force that "in spite of consistent attempts by the corporation to raise the salaries of engineers in manufacturing, engineers in other parts of the company were still paid more and had better career opportunities in moving quickly from engineering design to management."

Technical Management

Moreover, some of the problems in American manufacturing also can be attributed to managers who may have "lost contact with the technologies they are supposed to be managing" and therefore may not have the technical expertise to make difficult choices among emerging technologies—choices that play a major role in international competitiveness.

> . . . non-technical managers may understand the technologies being employed by their firms, but they don't have enough background to develop intuitions on which of the possible technologies now on the horizon are apt to be further developed and which are apt to be discarded. . . . By the time the answer is clear, foreign firms may have a

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[6] A report of the Task Force on A National Action Agenda for Engineering Education, American Society for Engineering Education, 1987.

[7] Compton, Dale W., *The Engineering Research Centers: Are We Prepared for the Challenges?* Systems Research Center, The University of Maryland, September 29, 1986, pp. 1-6.

two- to three-year lead in understanding and employing those new technologies.[8]

Upper management, in many cases, does not have the specialized technical background to independently evaluate progress in manufacturing technology development. If, in addition, management does not understand how these programs should be planned and conducted, it is truly unable to perform its function of overall control. One who understands neither what is being done nor how it should be done has small chance of influencing or even understanding the outcome.

The advancement of manufacturing technology is a very risky business. There are three basic ways it can gravely injure a company:

1. Resources can be wasted on inappropriate, technically hopeless, or badly managed projects.
2. Resources can be wasted on programs that develop innovations which appear to succeed but which produce a product of such poor quality that it injures or even destroys the company's competitive position.
3. One can avoid the first two risks by sticking to established technology until an opportunity to advance without risk comes along. In the meantime, management can issue general policy statements about dedication to innovation, while disapproving every specific project due to excessive risk. This policy can continue until the announcement of the closing of the plant because it can no longer compete.

Management is the reconciling of conflicts and minimizing of risk. However, conflict, risk, and uncertainty can be eliminated only by liquidating the business.

The exact definition of advanced manufacturing technology will vary from industry to industry and company to company. One company's radical innovation will be another company's mature technology. Obviously, the development of an advanced technology and the procurement of additional facilities for a mature one can and should be managed by different techniques.[9]

The Role of Engineers in Society

Engineers, and associated technicians and artisans, are obligated to produce safe products for the public. Engineers are responsible, legally, to assure that their work will perform the intended function, safely and reliably, with the least degradation of the environment, at the lowest reasonable cost. They also are responsible for creating the products which will compete in the international market.

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[8] Thurow, Lester C., "The Task at Hand", *The Wall Street Journal*, June 12, 1987, p. 46D.

[9] Miller, Jule A., "From Idea to Profit, Managing Advanced Manufacturing Technology," Van Nostrand Reinhold Company, New York, Preface, pp. vii–ix.

All engineers cannot have the overall responsibility of a Clifford Holland or a Joseph Strauss.[10] But engineers do not enjoy a stature in the scientific community or in society as a whole commensurate with their responsibilities. Indeed, engineers themselves often assume that the degree of importance of an individual to a mission depreciates from scientist *downward*, from professor of engineering, to an engineer with a Ph.D., to a design engineer, to an engineer with an undergraduate degree, to an engineer involved in manufacturing, to a designer, to a draftsman, to a technician, to a machinist and so on. Each person along the line, as a project proceeds from design through completion, is essential. Each has talent and a contribution to make. Each person adds value to the product. Each is important to someone who crosses a suspension bridge. Each is important to someone relying on the steering mechanism of a car driven on a crowded highway at 60 m.p.h.

Beyond Technical Expertise

We do not function in isolation. Industrial competitiveness also depends on gaining access to foreign technologies and foreign markets. Technical expertise is essential. But our work force also needs language skills and a far better understanding of the rest of the world.

> I think there is an abysmal ignorance about the state of technology in the rest of the world, the degree to which in many areas foreigners have overtaken us. . . . what [can we] do to give our work force a global perspective? What do we do to encourage people to travel? What do we do to encourage people to obtain language skills? . . . we have now the advantage of being in a sense number two in certain areas. We don't have to innovate totally. We can copy. We have learned that in our auto industry as the Japanese have moved in bringing with them the superior management techniques. But I think that exploiting this capacity to learn from others rather than to innovate and do it all alone is something that is going to be more open to us as, indeed, we become closer to a situation of first among

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[10] Clifford Holland was the principal engineer on the design and construction of the Holland Tunnel which is between New Jersey and New York City. Joseph Strauss was the principal engineer who designed and built the Golden Gate Bridge in California.

equals, if you will, rather than this dominant technological giant.[11]

Contribution of Foreign Nationals

The proportion of foreign nationals in American universities and in the science and engineering workforce has grown substantially in recent years. Jean-Jacques Servan-Schreiber and Herbert Simon of Carnegie Mellon University report:

> As of 1986, more than 300,000 foreign students were enrolled in American universities, 60 percent of them in technical fields. . . . The statistics show that from 1963 to 1983, the percentage of foreign-born doctoral students in industrial engineering grew from 7 percent to 68 percent; in mechanical engineering from 28 percent to 60 percent; in electrical engineering from 23 percent to 55 percent; in chemical engineering from 22 percent to 52 percent; in civil engineering from 37 percent to 63 percent. . . . As of last year, foreign students made up 40 percent of Ph.D. candidates in such fields as: cognitive science . . . medical information science . . . software engineering . . . and non-linear mathematics.[12]

In 1982, the proportion of foreign nationals in the American science and engineering workforce was 17 percent, up from 10 percent in 1972. And the proportion of foreign nationals in teaching, basic research and other positions is expected to continue to increase.[13]

Servan-Schreiber and Simon note: "For the first time in modern history, one country seems to serve, in the advanced sciences, as the university of the world." But the "intellectual migration" has sparked debate about whether it is "good for America to be educating the world's best and brightest" and whether it is "good for other countries to lose some of their best brains every year." The principal problem may be quite different: "We don't have too many foreign students, we have too few Americans. We are not attracting enough of our students into graduate schools", declared the director of the American Society for Engineering Education, Karl Willenbrock.

There are substantial benefits from continuing to encourage foreign students to attend American universities:

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[11] Hearing before the Technology Policy Task Force of the Committee on Science, Space, and Technology, 100th Congress, First Session, July 1, 1987 (No. 32). *The Effects of Technological Change on the Labor Force*, p. 147.

[12] Servan-Schreiber, Jean-Jacques and Simon, Herbert, "America Must Remain the World's University", *The Washington Post*, November 15, 1987, pp. C1–C2.

[13] Solomon, Steven, "American Laboratories, Foreign Brains", *The New York Times*, July 19, 1987, p. F8.

> Foreign students give the United States as much as they get. They are paying for their long years of study with the most precious and expensive commodity, the one the United States most needs today: more knowledge, new knowledge, provided by their labor. . . . Foreign students are needed to meet American research and development goals. If most of the foreign students were to return to their countries, it would be an American disaster. . . . The fact that a substantial number choose to return home is also very good. The great American knowledge-machine could not function for very long if it kept siphoning away the brain-power of America's partners around the world. The loss foreign countries experience when students come here is more than repaid by the new knowledge and skills they acquire when nearly half of them return. . . . We believe that a 50–50 trade is a fair ratio.[14]

Reciprocal Access to Foreign Research Institutions

In contrast to the 300,000 foreign students in American universities, only 30,000 American students attend universities abroad. Approximately 3 percent of these students study in technical areas such as engineering, computer science and physics.[15]

Some observers conclude this imbalance is simply the result of barriers in other countries. Japan typically is the case in point. But current discussions of reciprocal access of American students and scientists to foreign research institutions may oversimplify the problem. Charles Owens, former director of NSF's Tokyo office, cautions: "Access by U.S. researchers to Japanese laboratories depends at least as much on actions by Americans as it does on actions by Japanese.[16]

One problem is that Americans are not well informed about research opportunities in Japan. A second is language. The third is the different research and development systems in the two countries. Japan conducts most of its basic research in private industry and government agencies, while U.S. basic research is carried out in open universities. Moreover, until recently, Japan has not emphasized basic research in many fields but instead has put more emphasis on applied research and engineering activities—both are more likely to be proprietary.[17]

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[14] Servan-Schreiber, Jean-Jacques and Simon, Herbert, "America Must Remain the World's University", *The Washington Post*, November 15, 1987, pp. C1-C2.

[15] Ibid.

[16] Owens, Charles T., *Access to Japanese Laboratories*, Comments at the International Conference on Japanese Information in Science, Technology and Commerce, University of Warwick, September 1-4, 1987, pp. 1-7.

However, there have been recent changes. Japan has added two goals to its science policy: to encourage basic research and to "internationalize" the Japanese research and development system.[18] John H. Moore, Deputy Director of the National Science Foundation, notes that in the past 10 years, Japan has had the world's highest rate of increase in the publication of scientific articles.[19] And there are indications that Japanese laboratories would be quite willing to accept American researchers. But as Owens explains: "To date, we have done very little to test the degree to which appearance and reality coincide." [20]

CONCLUSIONS

1. While recognizing the overall strengths of American engineering education, the Task Force concludes that more emphasis is needed on training directly relevant to industrial needs: problem solving, systems engineering and quality control.

2. Some of the problems in American manufacturing also can be attributed to managers who may have "lost contact with the technologies they are supposed to be managing" and therefore may not have the technical expertise to make difficult choices among emerging technologies—choices that play a major role in international competitiveness.

3. Industrial competitiveness depends on gaining access to foreign technologies and foreign markets. While technical expertise is essential, our workforce also needs language skills and a far better understanding of the rest of world.

CHAPTER 2—MATHEMATICS AND SCIENCE EDUCATION

ISSUE

While state and local governments have placed increased emphasis on mathematics and science education, significant curriculum revisions in these areas would better prepare students to continue their education in engineering and technical fields.

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[17] Hearing before the Subcommittee on International Scientific Cooperation of the Committee on Science, Space, and Technology, 100th Congress, 1st Session, December 10, 1987 (No. 89). *Monitoring Technology Flow: Science, Technology, and Trade Policy Implications*, pp. 8–19, and Rasky, Susan F., "Groping for a New Order on Trade", *The New York Times*, August 30, 1987 p C1.

[18] Hearing before the Subcommittee on International Scientific Cooperation of the Committee on Science, Space, and Technology, 100th Congress, 1st Session, December 10, 1987 (No. 89). *Monitoring Technology Flow: Science, Technology, and Trade Policy Implications*, pp. 8–19.

[19] Ibid., pp. 75–92.

[20] Owens, Charles T., *Access to Japanese Laboratories*, Comments at the International Conference on Japanese Information in Science, Technology and Commerce, University of Warwick, September 1–4, 1987 pp. 1–7.

DISCUSSION

Our ability to increase the proficiency of American engineers and production workers is directly dependent on an adequate supply of highly educated high school graduates—the young people who will enter colleges and universities as well as industry. International comparisons of mathematics and science achievement point out weaknesses in American education, although the extent of the problem tends to be overstated.

The most widely reported international comparisons, based on 1964 data for mathematics and 1970 data for science, are difficult to interpret because they do not compare equal proportions of high school age groups. These international studies of achievement compared the average score of more than three-fourths of the age group in the U.S. with, for example, the average score of the top 9% in West Germany, the top 13% in the Netherlands, or only the top 45% in Sweden. The findings showed that the *average* high school student in the United States scored lower in international comparisons than the *average* high school student in other industrialized countries.

When the top students were compared, American students scored at about the same level in mathematics as their counterparts in many industrialized countries--though they still scored lower than their peers in Sweden, Japan and Israel. Top U.S. students also scored at about the same levels in science as students in other industrialized countries—better than students in France, Belgium, and Italy; not as well as students in New Zealand, England, and Australia.[21]

Preliminary results from a more recent international study of mathematics achievement, conducted in the 1981-1982 school year, show that American students in eighth grade—a grade where students in the U.S. and other countries are more likely to be comparable—performed at about the international median in algebra, arithmetic, and statistics. As shown on Chart D-1A, in geometry and measurement, the American students scored in the lowest quartile.

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[21] Husen, Torsten. "Are Standards in U.S. Schools Really Lagging behind Those in Other Countries?", *Phi Delta Kappan*, March 1983, pp. 455-461 and Rotberg, Iris C. "A New Perspective on Math and Science Education", *Phi Delta Kappan*, June 1984, pp. 668-673.

CHART D-1A.—EIGHTH GRADE (POPULATION A) ACHIEVEMENT COMPARISONS: U.S. AND INTERNATIONAL, 1981-82

[Percent of items correct]

Topic	United States (percent correct)	International (20 countries)		
		Lowest quarter of countries	Median	Highest quarter of countries
Arithmetic	51	45	51	57
Algebra	43	39	43	50
Geometry	38	38	43	45
Statistics	57	52	57	60
Measurement	42	47	51	58

Source: Curtis C. McKnight—see footnote 21.

These are not impressive findings, but they are certainly a more realistic picture of American mathematics education than the widely reported 1964 findings for 12th graders.

The 1981-1982 international test comparison for students in the last year of secondary school who were enrolled in advanced college-preparatory mathematics courses show: (1) American 12th grade students, on average, performed well below the average student in the final year of secondary school mathematics in other countries; and (2) American students in calculus classes performed at or near the international average in almost all content areas. Refer to Chart D-1B.

CHART D-1B.—TWELFTH GRADE (POPULATION B) ACHIEVEMENT COMPARISONS: U.S. AND INTERNATIONAL, 1981-82

[Percent of items correct]

Topic	United States			International (15 countries)		
	Precalculus	Calculus	Total	Lowest quarter of countries	Median	Highest quarter of countries
Sets and relations	54	64	56	51	61	72
Number systems	38	48	40	40	47	59
Algebra	40	57	43	47	57	66
Geometry	30	38	31	33	42	49
Elementary functions/calculus	25	49	29	28	46	55
Probability/statistics	39	48	40	38	46	64

Source: Curtis C. McKnight—see footnote 22.

In the United States, about one-fifth of the advanced mathematics students take calculus compared to all advanced students in most countries.

Again, student retention rates differ across countries. Hong Kong, which achieved the highest score on each topic, has a very selective school system. Japan, a close second in mathematics scores, does not.[22] Indeed, Japan has a higher secondary school retention rate than the United States.

A recent comparison of mathematics achievement of students in Illinois and Japan is shown in Chart D-1C.

CHART D-1C.—MATHEMATICS ACHIEVEMENT MEANS AND STANDARD DEVIATIONS FOR HIGH SCHOOL STUDENTS FROM JAPAN AND ILLINOIS

Variable	Japan (N: 1, 700)			Illinois (N:9, 582)		
	Percent	Mean	S.D.	Percent	Mean	S.D.
Sex:						
Male	58	42.08	9.37	50	19.88	9.55
Female	42	36.17	7.73	50	19.32	8.54
Age:						
15	27	34.35	6.79	07	16.72	7.72
16	36	40.73	8.91	80	20.49	9.22
17 or older	37	42.58	9.34	13	15.87	7.34

Source: Herbert J. Walberg—see footnote 23.

Since Illinois students perform at about the same level as U.S. students in general, the study is likely to have broader implications than just for Illinois. For this study, a mathematics test was given in 1981 to 1,700 Japanese and 9,582 Illinois high school students. The authors conclude:

> For all three age groups (15, 16, and 17 and older), the Japanese exceeded the Illinois students by two standard deviations. . . . Put another way, the average Japanese student outranked about 98 percent of the Illinois sample. At the upper ranges, the differences are still more striking. Only about 1 in 1,000 Illinois students attained scores as high as the top 100 out of 1,000 (or ten percent) of the Japanese students.[23]

Undoubtedly, there are cultural differences that affect student performance. For example, pressure for academic achievement is high in Japan. Japan has a uniform mathematics curriculum prescribed by the central ministry of education; students must take all the prescribed courses, while in the United States students may elect which courses to take. Moreover, as McKnight *et al.* note:

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[22] McKnight, Curtis C et al. *The Underachieving Curriculum: Assessing U.S. School Mathematics from an International Perspective*, a national report on the second international mathematics study, January 1987, pp. V-XIV, 12-29.

[23] Walberg, Herbert J. *et al.* "Mathematics Productivity in Japan and Illinois", Unpublished paper, University of Illinois at Chicago and Urbana, reported in Raizen, Senta A. and Jones, Lyle V., editors. *Indicators of Precollege Education in Science and Mathematics*, National Research Council, Washington, D.C., 1985, pp. 122-123.

> The extent of coverage by U.S. mathematics teachers of topics on the international test was typically at or below the international average for most content areas. . . . Within the United States, coverage varied a great deal among classes. That is, marked differences in opportunities to learn mathematics were found between students.[24]

In addition to international comparisons, comparisons of U.S. students today with U.S. students in previous years provide evidence of our major strengths and problems. Results are mixed:

> In general the achievement test scores of students who are likely to major in science or mathematics have remained high in these areas. Declines are more evident in tests that assess the basic scientific and mathematical knowledge of the general population.[25]

Significant curriculum changes are warranted. McKnight *et al.* make several proposals for restructuring the mathematics curriculum. Among these are recommendations for:

> A fundamental revision of the U.S. school mathematics curriculum, in both form and substance. . . . This activity should begin at the early grades of the elementary school. With respect to form, the excessive repetition of topics from year to year should be eliminated. A more focused organization of the subject matter, with a more intense treatment of topics, should be considered.
> Concerning substance, the continued dominating role of arithmetic in the junior high school curriculum results in students entering high school with very limited mathematical backgrounds. The curriculum for all students should be broadened and enriched by the inclusion of appropriate topics in geometry, probability and statistics, as well as algebra.[26]

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[24] Ibid., p. VIII.

[25] *On Math and Science Education in the United States*, Rotberg, Iris C., Remarks delivered at The Johns Hopkins University, April 10, 1985, pp. 11-13.

[26] McKnight, Curtis C. et al. *The Underachieving Curriculum: Assessing U.S. School Mathematics from an International Perspective*, a national report of the second international mathematics study, January 1987, p. XII.

The Task Force also encourages a comprehensive instructional program in the International System of Units (SI): meters, kilograms, seconds, radians, joules, newtons, and pascals.

The point is to improve course content rather than simply increasing course requirements. The major problem is that the population in general is not well-informed about basic scientific issues or about how to perform mathematical applications, such as problem solving. The emphasis of recent education reforms (and of mandated test programs which encourage course work that can be measured by objective test items) does little to improve the education of the large majority of students who might benefit more from curricula that are not designed along narrow disciplinary lines.

Unfortunately, these trends to require more courses without revising their structure and content seem inconsistent with some of the more useful mathematics and science curricula of the past 20 years. These curricula refocused the content (for example, by placing more emphasis on statistics and problem solving) and also attempted to give students a chance to understand the development of a limited number of major scientific concepts—but to understand these concepts in depth—rather than attempting to teach a lot of superficial facts in survey courses which are quickly forgotten.[27]

As more advanced artificial intelligence programs are developed, technology based learning devices, such as computer interactive video disc technology and easy access to reference information stored on laser discs can make an important contribution to student learning in these areas. Significant improvements in course content can be achieved by basing the software on the knowledge and experience of laboratory scientists routinely engaged in research activities. Nobel laureates like Phil Anderson have outstanding abilities in presenting the most difficult phenomena with extreme clarity.

A barrier to implementing curriculum changes is a shortage of mathematics and science teachers who are qualified to teach the new curricula.

> Reported teacher shortages result not only from the simple unavailability of "qualified" math and science teachers, which is very real in certain parts of the country, but also from budget constraints and from surpluses of teachers in other fields. For example, out-of-field teaching, which is used as one measure of teacher shortages, often reflects the placement of surplus teachers of other subjects who cannot be laid off because of their seniority. As a result,

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[27] Rotberg, Iris C. *On Math and Science Education in the United States.* Remarks delivered at The Johns Hopkins University, April 10, 1985, pp. 15–16.

> this measure may be used to describe shortages in algebra teachers merely because history teachers are being asked to teach algebra—not because there necessarily is a shortage of algebra teachers, but because the history teachers have seniority and cannot be laid off. Further, many school systems are likely to respond to increased math and science requirements by increasing out-of-field teaching, thereby reducing the quality of education in these fields—exactly the opposite of what is hoped for in the [educational] reforms. And it is often the lowest achieving students who get the least qualified teachers.
>
> And shortages of math and science teachers do not necessarily mean that these teachers can readily find jobs. For example, the State of Kentucky offered financial incentives for persons to enter teacher training programs in mathematics and science and then found that few available teaching positions existed for the first graduates. And in April 1983—the month in which the National Commission on Excellence in Education released its report, noting "particularly severe" shortages of math and science teachers—the Chicago press reported that the Chicago Board of Education had made substantial reductions in the number of math and science teachers during the past several years. Indeed, Chicago has a surplus of math and science teachers. Many of these teachers were working as substitutes and not necessarily in their fields of expertise. More often than not, such problems arise as a result of financial strain on States and school districts. It is not so much that the teachers aren't needed as that the districts can't afford to hire them.[28]

One reason it is so difficult to attract highly qualified teachers is the enormous increase in bureaucratic requirements accompanying recent education reforms.

> There are increases in *State* requirements which make Federal regulations (about which there has been so much concern in recent years) seem mild. There literally are thousands of new laws and policies. It is estimated that Colorado alone has 114 new laws affecting public schools. And one observer has referred to California's latest reform bill as a "garbage can"—a collection of everyone's bright ideas about what education should be like. It appears that State legislatures have moved from administrative and fi-

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[28] Ibid., pp 16–18.

> nance policies to direct control of curriculum and testing; noneducators seem to be making decisions about teaching principles and other instructional issues, while educators are spending their time worrying about money.
>
> All of this means that schools are likely to become even more boring places, less intellectually stimulating for students—and for teachers as well—than they are now, certainly not a trend that will make it easier to attract outstanding teachers and principals—without whom, of course, the education reforms can accomplish little. As a result of new requirements, teachers will have little discretion to make decisions about instruction and curriculum. Apart from autonomy, the sheer abundance of administrative work will mean less time for students. Unfortunately, these trends seem to run counter to the school effectiveness and management literature which emphasizes the importance of employees having at least the perception of some control over their own working environments. One observer summed it up this way, "Large size, bureaucratization, and fragmentation run counter to attempts to educate *individuals*. At the core of any genuine effort to provide education is the interaction between teacher and pupil."[29]

Another way to help ensure an adequate supply of qualified teachers is to encourage women, minorities, and the handicapped to enter the mathematics and science teaching profession. Our country's future hinges on having an ample supply of people who are knowledgeable in science and technology. By the year 2000, it is estimated that up to 85 percent of the new entrants into the workforce will be women, minorities, and the handicapped.[30] Therefore, it is important that they have sufficient access to training for professional careers in science and mathematics.

> The Nation can meet future potential shortfalls of scientists and engineers only by reaching out and bringing members of underrepresented groups into science and engineering.[31]

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[29] Ibid., pp. 18–19.

[30] Department of Labor, *Workforce 2000*, 1987, pp. xx–xxi.

[31] Task Force on Women, Minorities, and the Handicapped in Science and Technology, Executive Summary, p. 1.

CONCLUSIONS

1. Mathematics and science reforms should focus on curriculum content and teaching skills rather than simply increasing course requirements.

2. A fundamental revision of the U.S. school mathematics curriculum, beginning in the early grades of elementary school, is needed. This revision should include a more focused organization of the subject matter, less emphasis on arithmetic in the junior high school curriculum, less repetition from year to year, and a broadened curriculum including appropriate topics in geometry, probability and statistics, as well as algebra. Science courses also should present a more focused discussion of a limited number of major scientific and technological concepts to give students an opportunity to understand these concepts in depth.

3. The Technology Policy Task Force recognizes serious problems in the education field. An excessive number of young citizens in high schools and colleges do not have an understanding of mathematics and science which will provide them with access to the science and engineering fields. The Task Force refers to the recent report issued by the Carnegie Foundation for the Advancement of Teaching. The Task Force has set aside further effort in this area until early 1989, at which time, this subject will be reviewed by the Committee for possible further action.

4. The significant influx of women, minorities, and the handicapped into the labor force requires attracting a higher proportion of these groups into science and technology careers, including teaching, and providing them with the opportunity to participate fully in the science and engineering workforce.

Chapter 3—Urban Education

ISSUES

Because a large number of urban school children are not being properly educated, the United States can anticipate severe social problems in an economy where a significant proportion of the population may lack the qualifications to compete for middle-income jobs in high technology and information industries.

Compounding the problem is the recent decline in college enrollments of low-income students particularly among blacks.

DISCUSSION

Information received by the Task Force indicates that unacceptable conditions in urban schools have reached crisis proportions. The Board of Trustees of the Carnegie Foundation for the Advancement of Teaching recently concluded:

> . . . America continues to face the very real possibility of the two separate societies envisioned by the Kerner Commission two decades ago. In its prophetic statement, the Commission warned of a social and economic division in the nation "so deep that it would be almost impossible to unite."[32]

Equally discouraging is that many who will be "left out" could have become high achievers. Thus, the entire society will lose. Nowhere will this problem be more acute than in America's high technology economic development which depends on the expertise of its engineers and production workers. And it represents a serious personal loss to these young people who will be relegated unnecessarily to low-paying, nonessential jobs or to unemployment.

> In almost every big city, dropout rates are high, morale is low, facilities often are old and unattractive, and school leadership is crippled by a web of regulations. . . . the failure to educate adequately urban children is a shortcoming of such magnitude that many people have simply written off city schools as little more than human storehouses to keep young people off the streets. We find it disgraceful that in the most affluent country in the world so many of our children are so poorly served.[33]

The following facts illustrate the seriousness of the problem.

- The national dropout rate is almost 700,000 students per year.[34] In urban schools, about a third of the students leave before completing high school.[35]
- The students who remain in school have high truancy rates:

  In New York City, at academic high schools geared to prepare students for college . . . one out of every five students was absent on any given day. And in four of those schools, the absence rate approached one in three. 'I made guest appearances when I was enrolled,' said a student who transferred to an alternative high school.[36]
- Reading scores are well below national averages: At a Chicago high school, only 10 percent of the entering tenth

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[32] The Carnegie Foundation for the Advancement of Teaching, Board of Trustees, *An Imperiled Generation: Saving Urban Schools,* Princeton, New Jersey, 1988, p. xi.

[33] Ibid., p. ix.

[34] Ibid, p. xi.

[35] The Carnegie Foundation for the Advancement of Teaching, Board of Trustees, *An Imperiled Generation: Saving Urban Schools,* Highlights of the Comprehensive Carnegie Foundation Plan for Urban School Improvement, Princeton, New Jersey, 1988, p. 1.

[36] The Carnegie Foundation for the Advancement of Teaching, Board of Trustees, *An Imperiled Generation: Saving Urban Schools,* Princeton, New Jersey, 1988, p. x.

> graders were able to read effectively. In New Orleans, the average high school senior was reading at a level exceeded by 80 percent of the students in the country. In a Houston elementary school, half the students had to repeat a grade because of unsatisfactory academic progress. . . . Seventy-five percent of the high school freshmen in Chicago had reading test scores below the national average, and only five of that city's 64 public schools had averages approaching national reading norms. Only 229 of the 1,918 students in one Los Angeles high school scored at grade level in reading. . . . the city-wide Educational Coalition in Boston . . . concluded: 'Not only do 44 percent of [Boston's] high school students drop out before they reach 12th grade, but over 40 percent of those who do reach 12th grade score below the 30th percentile on a standardized reading test. They may graduate but they are functionally illiterate.' [37]
>
> - In addition to substandard physical surroundings, many urban students and teachers must deal routinely with violence, drugs, and other social problems: "In Boston schools last year 55 students were expelled for carrying guns and 2,500 must report to police probation officers for past offenses." A principal in New York asked for a transfer from a high school "where he had clearly lost control of violence-prone students and where students in the cafeteria stomped a girl so brutally they broke her ribs". A high school principal in Philadelphia "talks of confiscating crack bags from student pushers in a neighborhood torn by gang wars and racial strife. . . . In St. Louis, 1 of 4 girls in public schools becomes pregnant before reaching her senior year. . . . In Philadelphia, an administrator describes conditions at an inner-city school: "people coming to class high, not just pupils but teachers as well; filthy bathrooms, gang intimidation, nowhere to hang coats without being stolen." [38]

There are some exceptions. The Carnegie Foundation describes outstanding principals and teachers "who have turned failing schools around":

> One junior high school principal in New York City's South Bronx, for example, has built a reputation of excellence that even attracts recruiters from elite private high schools. In Los Angeles, a principal with vision has in-

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[37] The Carnegie Foundation for the Advancement of Teaching, Board of Trustees, *An Imperiled Generation: Saving Urban Schools*, Princeton, New Jersey, 1988, p. x.

[38] "Getting Tough", *Time*, February 1, 1988, pp. 52-55.

> spired both teachers and students to high levels of achievement. There are gifted teachers who believe in students and conduct their classes with the expectation that learning will occur. . . .[39]

But for most inner-city students the situation is grim. The Carnegie Trustees conclude that improving the education of urban youth is the "most critical issue the Foundation has addressed." [40] Failure to improve urban schools will have serious consequences for the ability of inner-city students to compete for middle-income jobs and, indeed, for the nation's economic strength. The problem is compounded by structural changes in the U.S. economy. Traditional manufacturing jobs requiring less than a high school education have declined while jobs—particularly in information and high technology industries—which require more education have increased. Central city residents with higher education levels are able to take advantage of those new job opportunities, but those with less education often remain unemployed or find jobs only in low-paying occupations.[41] According to the Carnegie Trustees:

> . . . This nation must confront, with urgency, the crisis in urban schools. Bold, aggressive action is needed now to avoid leaving a huge and growing segment of the nation's youth civically unprepared and economically unempowered. This nation must see the urban school crisis for what it is: a major failure of social policy, a piecemeal approach to a problem that requires a unified response.[42]

The Carnegie Trustees recommended a plan organized around four priorities:

- Affirming that every student can succeed: "Urban schools should have high expectations for all students, not just the most advantaged."
- Building an effective governance arrangement: "The excessively centralized bureaucratic control of urban schools must end." . . . But, "each school must be held accountable for its work . . . By mandating, in detail, how schools must be run, the pro-

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[39] The Carnegie Foundation for the Advancement of Teaching, Board of Trustees. *An Imperiled Generation: Saving Urban Schools*, Princeton, New Jersey, 1988, p. ix.

[40] The Carnegie Foundation for the Advancement of Teaching. *News*, March 15, 1988, p. 2.

[41] Wilson, William Julius, *The Truly Disadvantaged: The Inner City, the Underclass, and Public Policy*, University of Chicago Press, Chicago, Illinois, 1987; Greenstein, Robert. "Prisoners of the Economy", *The New York Times Book Review*, October 25, 1987, pp. 1, 46–47; and Field Hearing before the Subcommittee on Science, Research and Technology of the Committee on Science, Space, and Technology, 100th Congress, First Session, Research Triangle Park, North Carolina, November 9, 1987 (No. 95). *Scientific and Technical Literacy in the Workforce*, pp. 108–124.

[42] The Carnegie Foundation for the Advancement of Teaching. *News*, March 15, 1988, p. 4.

fessionalism of the staff is undermined and individual teachers are robbed of authority to act." This lack of authority is combined with unpleasant and often unsafe working conditions:

> In the most troubled schools, teachers, with good reason, do not feel safe in the halls, in the parking lots, or even in the classrooms. Violence levels are high and assaults against teachers are not uncommon. A Carnegie Foundation poll of teachers nationwide revealed that over half the teachers in urban schools consider vandalism and disruptive class behavior a problem in their schools. . . . every school should have not only high expectations for academic achievement but high expectations for conduct too. Standards of discipline must be consistently and sensitively enforced throughout the school. Education and civility are linked.

- Introducing at every school a comprehensive program of renewal:

  Special emphasis should be given to preschool and early education. . . . School size is crucial, too. All urban schools should be organized into small units—schools-within-schools—to make it possible for teachers to work together and overcome the sense of isolation felt by young people in the inner city. Every student should be well known and counseled by a caring mentor. Every school should have clearly defined goals and . . . curriculum. . . . The urban school should be flexible in its scheduling arrangements. . . . Good facilities are essential. . . . Federal support is needed to permit the refurbishing of old buildings and the construction of new facilities so students can learn in safe, attractive settings.
- Creating a network of support beyond the school. Urban school systems cannot accomplish these changes in isolation: "Parents, college teachers and business leaders, as well as government officials at the state and national level, must be partners in renewal." [43]

In a statement accompanying the report, Ernest L. Boyer, Foundation President, recommended a National Forum on Urban Schools:

> The President should declare that effective education for *all* children is a top priority for the nation. What we need is a National Forum on Urban Schools—a meeting at the

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[43] The Carnegie Foundation for the Advancement of Teaching, Board of Trustees. *An Imperiled Generation: Saving Urban Schools*, Princeton, New Jersey, 1988, pp. XI-XIV and 5-7.

> summit, perhaps convened by the President, to bring together influential leaders from every major sector. The Forum would be an ongoing organization, leading the crusade for more local, state, and federal support and monitoring progress in urban schools. The goal should be to have quality education for all children by the year 2000. Once America was challenged to land a man on the moon within a decade. And we did. This same spirit must be directed toward the education of our least advantaged children. In saving an imperiled generation, we save ourselves.[44]

The Carnegie Trustees acknowledge there are no quick fixes. The problems of urban schools reflect more general societal problems. The trustees recommend a new National Urban Schools Program "similar in spirit" to the Rural Extension Act to help farmers. While not reducing state and local responsibility for education, the program would provide additional federal support for basic skills programs, facilities, school innovation, and other central city education programs.

As part of increased federal support for urban schools, a grants program inviting urban school districts to submit bids to establish pilot programs would provide useful information. Districts could propose programs in one or a combination of areas on a trial basis. A number of programs have shown evidence of making a difference.

- Small school units as recommended by the Carnegie Trustees. Small school size by itself does not increase student achievement. But, if managed well, small schools provide learning and motivational opportunities which are more difficult to achieve in less personal environments.
- Magnet schools which provide a general or specialized curriculum to students from across the school district. These schools typically attract additional resources but may have the disadvantage of reducing resources available to neighborhood schools. Like small schools, magnet schools provide increased learning opportunities. In some school districts, they also have attracted the middle class, both black and white, back into the public schools.
- College scholarship programs designed to increase achievement by offering financial assistance to eligible students. Current scholarship programs range from city-wide programs supported by local industry and foundations to the widely publicized examples of classrooms "adopted" by wealthy sponsors who offer

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[44] The Carnegie Foundation for the Advancement of Teaching. *News*, March 15, 1988, p. 2.

college scholarships as well as high school tutoring and other support services. Under the federal grants program proposed here, school districts might bring existing sources of support to students' attention, raise funds from local businesses and foundations, or use some of the grant money to provide direct scholarship assistance.

- Community support programs. Industry and university support has increased the effectiveness of schools in some inner cities by offering both financial assistance and direct services—college scholarships, guaranteed employment to high school graduates, special university services to entering students, and services ranging from accounting to tutorial help in the public schools themselves.[45]
- Plans to encourage principal and teacher accountability. Under these plans, individual principals and teachers are given more responsibility for education but also are accountable for results. Effective plans set realistic goals: The point is to measure student progress but schools are not expected to meet arbitrary test cutoff points.[46]

Each of these programs requires resources which may not be available under many districts' current budgets and constraints. A federal grants program with a strong evaluation component would give central city districts an opportunity to carry out and assess programs they consider potentially effective. These programs constitute one step in addressing a complex problem which goes well beyond the education system. But as part of a broader national focus on inner cities, they would provide information useful to other cities—as well as to states and the Federal Government—in setting future priorities for urban education.

Access of Low-Income Students to Higher Education

Closely associated with problems in urban education is the recent decline in college enrollments of low-income students, particularly among blacks. As a result, many blacks may not be gaining the education needed to compete for the growing number of jobs in information and high technology industries. Black high-school graduates are increasingly going into the military or attending proprietary schools. But many are unemployed: Black male teenage unemployment is 34 percent, almost triple the unemployment rate for white males.[47]

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[45] From a forthcoming Rand Corporation report.

[46] Ibid.

[47] Wilson, William Julius, *The Truly Disadvantaged: The Inner City, the Underclass, and Public Policy*, University of Chicago Press, Chicago, Illinois, 1987 and Greenstein, Robert, "Prisoners of the Economy", *The New York Times Book Review*, October 25, 1987, pp. 1, 46–47.

The fact that many minority youth come from low-income families living in high-crime areas and from poor schools is a major factor in the low college attendance rates.[48] But another may be inadequate funds. Kathryn Mohrman, a Brookings guest scholar, describes the changes in student aid:

> Over the last decade, two developments—a decline in the real value of student aid and a shift in emphasis from grants to loans—may have begun to erode the educational philosophy underlying the financial aid programs and perhaps even the public and private benefits those programs have yielded. . . . In a single decade, loan programs have become the major funding mechanism helping needy students gain access to college.[49]

Decreases in student grants may have had unintended consequences for minority enrollment in higher education. Some minority youth may choose not to enroll at all. Others may choose lower-quality institutions to reduce the size of their loans:

> . . . The drop in both the number and the proportion of minority students in postsecondary education is disturbing for several reasons. Fewer blacks in particular will be qualified with a college degree to become the professionals that this nation will need in the years ahead . . . Moreover, many studies have shown that one of the most important factors influencing the decision to go to college is parental educational level. If today's minority high school graduates choose not to participate in further education, out of concern for loan burdens or for other reasons, their children may not be as likely to go to college as the next generation of white and Asian students. Not only is this nation failing to reach its goal of equal educational opportunity for today's young people, but it is sowing the seeds for continuing gaps in the future.[50]

One way of dealing directly with the financial problems of low-income students is to redirect federal aid for loans back to grants, as Mohrman recommends. Such a method could help provide incentives for elementary and high school students to excel in order to earn college tuition. In addition, witnesses before the Task Force made other proposals for financing education and training which circumvented traditional funding methods in an attempt to increase resources. One suggestion was for a federal loan program which would make it possible for anyone who wanted to undertake higher education or retraining in a recognized institution to receive full resources from the government and then be liable to pay it back through income taxes contingent on future income.[51] Currently there are small scale programs which link loan repayment to income, for example, Harvard Law School's loan forgiveness programs for students entering public service careers and the Education Department's experimental income-contingent repayment plans.[52]

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[48] Collison, Michele N-K, "More Young Black Men Choosing Not To Go To College", *The Chronicle of Higher Education*, December 9, 1987, pp. A1, A26–27.

[49] Mohrman, Kathryn, "Unintended Consequences of Federal Student Aid Policies", *The Brookings Review*, Fall 1987, pp. 24–30.

[50] Ibid.

CONCLUSIONS

1. The Task Force supports the recent proposal of the Carnegie Trustees for a National Urban Schools Program "similar in spirit" to the Rural Extension Act to help farmers.
2. High priority should be given to federal student aid policies which would increase the access of low-income students to higher education.

CHAPTER 4—TRANSITIONAL PROGRAMS AND CONTINUING EDUCATION

ISSUE

Changes in the global economy have caused many American workers to lose their jobs in traditional manufacturing industries. Some of these job losses also resulted from technological advances which led to increased manufacturing productivity. Although these advances have a positive impact on the economy as a whole, they often cause hardships for workers in specific industries.

DISCUSSION

Technologies always have had a significant effect on the work force. The history of the Chesapeake Bay serves as one illustration of the way new technologies impacted people's lives in that area. In colonial America, the Bay served as a major highway for commerce. Sailing vessels were used to haul food, lumber and goods received from Europe. But these sailing vessels gradually were replaced by steam powered stern wheelers which, in turn, were replaced by diesel powered vessels and finally by trucks. In succession, sail makers lost their jobs, men who knew steam engines lost their jobs because they were not able to work on diesel engines, and eventually shipbuilders lost their jobs. Further, many of the new jobs in the trucking industry were to be found only in cities which were too far away for workers to relocate.

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[51] Hearing before the Technology Policy Task Force of the Committee on Science, Space, and Technology, 100th Congress, First Session, July 1, 1987 (No. 32). *The Effects of Technological Change on the Labor Force*, pp. 133–134.

[52] Wilson, William Julius, *The Truly Disadvantaged: The Inner City, the Underclass, and Public Policy*, University of Chicago Press, Chicago, Illinois, 1987 and Greenstein, Robert, "Prisoners of the Economy", *The New York Times Book Review*, October 25, 1987, pp. 1, 46-p47.

The Task Force recognizes that the development of new technologies has caused many American workers to lose their jobs. Indeed, technological advances are a mixed blessing. Although they contribute to employment for the economy as a whole, they often have adverse effects on workers in specific industries.

There is a basic dilemma: The loss of blue collar jobs in America is evidence of increased productivity. It is the transition across the working life and from one generation to another which needs to be addressed:

> Increased manufacturing production in developed countries has actually come to mean *decreasing* blue-collar employment. As a consequence, labor costs are becoming less and less important as a "comparative cost" and as a factor in competition. While the trend has been running for a long time, it has lately accelerated to the point where—in peacetime at least—no increase in manufacturing production, no matter how large, is likely to reverse the long-term decline in the number of blue-collar jobs in manufacturing or in their proportion of the labor force. . . . This trend is the same in all developed countries, and is, indeed, even more pronounced in Japan . . . .[53]

A number of other changes in the global economy also contributed to job losses in manufacturing:

- decreased product sales, induced initially by the high value of the dollar, which once lost is difficult to reestablish;
- increased competition from other countries;
- the world debt crisis which has resulted in a loss of markets in debtor countries;
- oversupply of certain commodities;
- substitution of products; and
- shifting consumer preferences.

In some of these areas, the conditions may have been caused by factors which were out of U.S. control but to which the nation needs to react. In other cases, internal policies created the problem. Regardless of the cause, these developments have done considerable damage to the labor force in traditional manufacturing fields. Many of the workers who lost their jobs have been absorbed in the job market, but at lower wages. Others have remained unemployed for a variety of reasons: inadequate training or education, lack of labor mobility, age, etc. Under the circumstances, there clearly is a need for increased attention to technology applications and innovation, long-term product development, and product quality.

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[53] Drucker, Peter F., "The Changed World Economy," *Foreign Affairs*, Spring, 1986, pp. 769-791.

This chapter discusses several proposals for addressing employee dislocations. Many of the proposals are intended to provide alternatives to special protection by easing the transition through difficult periods. While the Task Force has not taken a position on specific alternatives, it recommends that high priority be given to public policies for alleviating adverse effects of industrial transition on workers.

Continuing Education of the Labor Force

The technological revolution has accelerated changes in the workplace which will require most people to learn new skills—and sometimes new careers—throughout their lifetime. *The Economist* concludes: ". . . the half-life of people's knowledge is contracting so fast that it now almost equals the time taken to acquire it." [54]

The United States has what *The Economist* calls a "vast non-system" of higher education and training for adults. Large numbers of adult Americans attend colleges and universities or take courses sponsored by a range of other organizations—corporations, labor unions, professional associations, government organizations. It is estimated that more than 45 million adult Americans—more than a quarter of the adult population—are currently taking courses. Approximately 8 million adults participate in corporate training programs alone. According to *Science,* "the dollars spent and the numbers of company students trained are comparable to the totals experienced by all the country's 4-year colleges and universities.[55] Chart D-2A provides additional information on adult education activity.

CHART D-2A.—ADULT EDUCATION ACTIVITY IN THE UNITED STATES

Reasons for study (1984) [1]	Number of courses taken (000's)	Percentage of total courses provided
To get new job	4,803	12
To advance in current job	19,702	48
Other job related	1,656	4
Not job related	14,590	36
Total courses taken	40,751	100

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[54] "Training for Work: In Search of Missing Skills," *The Economist*, December 20, 1986, pp. 93-101.

[55] Abelson, Philip H. "Continuing Education for Blue-Collar Workers," *Science*, November 13, 1987, p. 875.

Provider of instruction (1981) [2]	Percentage of total courses provided
School (High; trade and vocational; 2 and 4 yr. colleges; universities)	53.9
Business or industry	13.7
Private community organization	8.5
Labor or professional organization	5.0
Government agency	7.8
Other	11.1
Total	[3] 100

[1] U.S. Bureau of the Census, 1986. *Statistical Abstract of the United States: 1987.* 107th ed. Washington, D.C.: U.S. Government Printing Office.

[2] U.S. Bureau of the Census. 1984. *Statistical Abstract of the United States: 1985.* 105th ed. Washington, D.C.: U.S. Government Printing Office.

[3] 24.8 percent of all courses were provided by employers.

Peter Drucker notes:

> . . . educators will have to accept that schooling is not for the young only and that the greatest challenge—but also the greatest opportunity—for the school is the continuing relearning of already high-schooled adults. So far we have no educational theory for these tasks. . . . But in the United States, at least, practice is far ahead of theory. To me the most positive development in the last twenty years, and the most encouraging one, is the ferment of educational experimentation in the United States—a happy by-product of the absence of a "Ministry of Education"—in respect to the continuing learning and relearning of adults, and especially of highly schooled professionals. Without a "master plan", without "educational philosphy", and indeed, without much support from the educational establishment, the continuing education and professional development of already highly educated and highly achieving adults has become the true "growth industry" in the United States in the last twenty years.[56]

Declining Tariffs to Finance Worker Readjustment Programs

Robert Z. Lawrence of the Brookings Institution suggests that revenues raised from declining tariffs and from auctioning off existing quotas should be earmarked for assisting workers adversely affected by imports. Under this proposal, tariff rates would be scheduled to decline over time. All existing quotas and other quantitative restrictions would be converted to their tariff equivalents by auctioning them off to the highest bidder. In his view, the major advantage of earmarking funds is to provide a "safety valve" against protectionist pressures as well as to raise revenues for programs which have become increasingly ineffective because of inadequate funding.[57]

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[56] Drucker, Peter F., *Innovation and Entrepreneurship: Practice and Principles*, New York, Harper & Row, 1985, pp. 253–260.

But some analysts describe practical difficulties in attributing worker dislocations to specific causes, like imports, technology, or poor management. David C. Mowery, Study Director of the Panel on Technology and Employment, notes:

> . . . targeting workers according to the cause of their displacement would induce severe administrative problems and result in severe delays in the delivery of services, simply because it's so difficult to determined the precise cause of displacement of an experienced worker.[58]

However, Gary Clyde Hufbauer and Howard F. Rosen of the Institute for International Economics, argue that self-financing options (i.e., the use of revenues from declining tariffs and auctioning off existing quotas) are essential to the effectiveness of adjustment programs since *general* revenues provide only a small proportion of the funds needed to serve displaced workers. To address the practical difficulties in attributing worker dislocations to specific causes, they propose that all workers present in the declining industry on a specific date should receive assistance regardless of the assumed cause:

> . . . our calculations . . . suggest that tariffs (or auctioned quotas) alone would provide more than enough revenue to handle the adjustment needs *of all* departing workers and firms, whatever the cause of their exit from the industry.[59]

Basic Skills Programs

Students who leave high school without basic competencies in communication and problem solving require further opportunities to gain these skills. Eli Ginsberg of Columbia University suggests:

> The Federal Government [should encourage] state and local governments and the private sector to provide second and third chance opportunities to young people who drop out of high school lacking basic competencies—arithmetic, reading, communication—without which they can't get or

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[57] Hearing before the Technology Policy Task Force of the Committee on Science, Space, and Technology, 100th Congress, First Session, July 1, 1987 (No. 32). *The Effects of Technological Change on the Labor Force*. pp. 56–59.

[58] Ibid., p. 81.

[59] Hufbauer, Gary Clyde and Rosen, Howard F. *Trade Policy for Troubled Industries*, Institute for International Economics, Washington, D.C., March 1986, pp. 1–43 and 67–94.

> hold a job in the service economy that currently provides 3 out of every 4 jobs.[60]

Dr. Ginzberg's major concern is that "many minority youth are coming into the labor force blocked from competing for mainline jobs" because of high dropout rates in the inner city. In his view:

> We have a whole section of our population that is cut off from the new work force. That is the single most serious problem that I see in the American economy today. And that means that since I don't believe we can restructure the elementary and secondary schooling very quickly . . . we have to have second and third chance opportunities.[61]

These basic skills programs would be more effective if they were linked to jobs. Dr. Ginzberg recommends a federally funded jobs program with a basic competencies component:

> Since the young people who drop out of school have a negative image of the educational process, it is important to try to reduce the dropout rate by offering them part-time jobs in which they may be interested. Similarly, after they drop out, one cannot get them back into school simply for remedial work. Such an effort must be linked to jobs and training.[62]

Arnold Packer of the Hudson Institute also stresses the importance of integrating basic skills programs for adults with vocational training:

> Generic skills would be taught for clusters of jobs. Students interested in construction would learn to read blueprints and prepare cost estimates. Those interested in health care would get to see patient charts and insurance forms.
>
> Learners would control the pace of instruction, based on their own needs and knowledge. Students would learn by engaging in realistic workplace problem-solving. Multimedia training aids would replace exclusive reliance on books and other forms of text. New educational technology—such as interactive video discs combining video, audio, text and graphic animation—would give educators the capacity to meet these specifications . . .[63]

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[60] Hearing before the Technology Policy Task Force of the Committee on Science, Space, and Technology, 100th Congress, First Session, July 1, 1987 (No. 32). *The Effects of Technological Change on the Labor Force*, p. 152.

[61] Ibid., p. 128.

[62] Ibid., p. 154.

[63] Packer, Arnold, "Retooling the American Worker," *The Washington Post*, July 10, 1988, p. C3.

The Administration has recommended action by a proposed change to the current Summer Youth Program.

> The Administration therefore proposes to change the current summer program to give local areas flexibility in designing a program of jobs, basic skill remediation, and vocational training for low-income youth. Under the proposal, the resources would be available for year-round programs of assistance, for subsidized summer jobs, or for both activities, depending on local choice. The Administration is proposing $718 million for this program for 1989, the same as enacted in 1988.[64]

Reemployment Programs

Witnesses advised that incentives to industry and workers should expedite the reemployment of displaced workers, noting that some programs have delayed adjustment by giving extended unemployment compensation payments without positively encouraging workers to find alternative employment.

Lawrence notes:

> . . . there is indeed something very traumatic and difficult for a worker who was earning a high wage to now have to experience a precipitous decline in his or her income. Indeed, there is an incentive to delay adjustment because of that erosion in the income that the worker would experience.

He recommends a form of wage insurance for displaced workers which would compensate them for a proportion of the decrease in their wages for a specified time period.[65]

Strengthening Title III of the Federal Job Training Partnership Act (JTPA)

Mowery recommended strengthening Title III of the Federal Job Training Partnership Act (JTPA) by: (1) increasing JTPA's coverage of displaced workers from the current level of 6–7 percent; (2) broadening the range both of employment and training services; (3) broadening income support for displaced workers engaged in training; and (4) revising state unemployment compensation laws to guarantee that displaced workers who are eligible for unemployment compensation can receive benefits during training.[66]

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[64] Fiscal Year 1989 Budget, *Special Analysis Section*, p. H–9.

[65] Hearing before the Technology Policy Task Force of the Committee on Science, Space, and Technology, 100th Congress, First Session, July 1, 1987 (no. 32). *The Effects of Technological Change on the Labor Force*, pp. 25–26, 57, 59.

[66] Ibid., pp. 88–89.

As the proportion of existing labor force participants to new entrants increases over the next decade, policies to retrain existing workers will become increasingly important. But strong employment counseling and placement services remain the most practical alternative for many displaced workers. As Ginzberg put it:

> It is desirable to have reasonable amounts of retraining money in the JTPA program available for workers who need and want and can profit from retraining. But the sad fact is that many workers with minimal educational competencies cannot be effectively retrained. . . . I have long favored a federally-financed jobs program at minimum wages—with remedial education opportunities—for those who need a job.[67]

Evaluation of federal employment and training programs remains a problem. We do not yet have rigorous evaluation data to assess the effectiveness of these programs. Although there is some evidence—in part anecdotal—that the programs improve employment prospects, there is little knowledge to provide guidelines for program design.[68]

Early Retirement Options

Some witnesses stressed the importance of an early retirement option. They argued that most of America's industrialized partners provide these options as a matter of social equity as well as to facilitate structural changes. Ginzberg suggested an amendment to Social Security allowing workers who are unemployed due to plant shutdowns, to receive reduced benefits if they are between 58 and 62 and have 20 or more years employment. He argued that using the Social Security system would "avoid putting the costs of large underfunded pension plans on the federal system or the U.S. Treasury." Ginzberg noted that it is common practice for European countries to offer early retirement at age 55 or 58: "It looks to me like a minimum kind of a thing that a civilized society might be willing to do."[69]

Lynn Williams, President of the United Steel Workers of America, also stressed the importance of an early retirement option:

> . . . workers are unable to be sympathetic with the goals of industrial transition since there are little transitional programs assisting them.[70]

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[67] Ibid., p. 153.

[68] Ibid., p. 89.

[69] Ibid., p. 129.

[70] Ibid., p. 6.

Advance Notice of Plant Shutdowns or Large Scale Layoffs

Several witnesses advocated mandatory advance notice. Mowery recommended federal legislation requiring that as many workers as possible receive at least two to three months advance notice of plant shutdowns or large-scale layoffs. Small firms or firms encountering unforeseen business circumstances would be exempted. An alternative would be to reduce the tax burden on firms providing advance notice.

Voluntary advance notice appears to provide substantial notice to only a small proportion of the work force. Mowery noted that:

> Under the current voluntary system . . . the costs of plant closings in which advance notice is not provided are borne primarily by the taxpayers (including other employers) and the affected workers. . . . Requiring advance notice can redistribute the costs of layoffs and plant shutdowns.[71]

Ginzberg argued:

> If you can have management have all kinds of these golden parachutes, the least you can do is if you've had a worker for 25 years on your payroll, to give him a couple of months notice.[72]

Lawrence compared advance notice with a requirement that landlords give their tenants 30 days' notice:

> . . . it just seems to me that dropping people, particularly when it's en masse, in an environment is just something which is basically inhuman. . . . I haven't seen the property market come grinding to a halt as a consequence of mandatory advance notification for property, and I would do the same thing for plant closing.[73]

Strassmann expressed his opposition to plant closing legislation because he felt it was impractical and would not achieve its purpose. He suggested instead a profit-sharing plan which he believes would be more effective in alleviating the basic problem:

> . . . 90 days is just not enough for someone to be able to reconfigure their life. . . . those companies that are involved in gain-sharing . . . these workers have a long-term understanding and information about the competitive viability of the firm . . . .[74]

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[71] Ibid., pp. 89-90.

[72] Ibid., p. 125.

[73] Ibid.

[74] Ibid.

CONCLUSIONS

The technological revolution has accelerated changes in the workplace which will require most people to learn new skills—and sometimes new careers—throughout their lifetime.

While the Task Force has not taken a position on specific proposals for alleviating adverse effects of industrial transition on workers, it emphasizes the importance of public policies for easing the transition through difficult periods and helping workers move into internationally competitive industries.

SECTION E—INDUSTRIAL SECTORS

CHAPTER 1—MANUFACTURING

ISSUES

Most areas of U.S. manufacturing have lost some fraction of their traditional share of both domestic and foreign markets in spite of recent gains in productivity. Of even more concern than these losses are the trends suggested by manufacturing data collected over the last two years. A primary responsibility of the Federal Government is to provide for the economic security of the U.S. National policy objectives, are not currently or collectively structured to provide the incentives for U.S. industry to concentrate on restoring a balance in trade.

DISCUSSION

Manufacturing employs approximately 20 million Americans and provides jobs for another 40 million in the service sector. The total value of goods manufactured in America in 1987 was $2,408 billion. Manufacturing has been and will remain critical to the economic health of America.

The necessity to provide ourselves and our allies with war materials caused the United States to expand its industrial capacity during World War II. This expansion was essential for combating the threat of Germany in Europe and Japan in the Pacific. By using European science and developing technology and products from that science, the U.S. was able to overwhelm its adversaries. For example, we used the discovery of uranium fission in Germany to develop the nuclear bomb. Later, that technology was advanced for peaceful applications. The development of quantum mechanics in Germany promoted the development of semiconductor technology in the U.S. The development of jet propulsion in Germany and later in the U.K. led to our development of jet aircraft. It is ironic that the U.S. developed a great manufacturing capability on the basis of European scientific discoveries; 40 years later, Japan developed a great manufacturing industry based on scientific breakthroughs in the U.S.

At the end of World War II the United States was the only world power to emerge with industries intact. England and France, although both victors in this war, were financially exhausted. The

Soviet Union was also a victor but was physically ravaged and burdened with an economic system which inhibited industrial growth. Much of post war eastern Europe was under Soviet domination and Japan and Germany were devastated.

Many Americans fail to recognize that the outcome of World War II placed our manufacturing industries in a vital position of monopoly. No other country's industries were competitive with ours.

> I think we made a major miscalculation. We believed that which was a historical accident was, in fact, a permanent condition. . . . And in the ensuing years, our largest companies and our largest industries became almost unconsciously de facto monopoly companies. That is true in steel, and it's true in auto, and it's true in most areas. . . . But in the true sense U.S. industries were not innovative technologically and creatively." [1]

In addition to having the only manufacturing industry that survived World War II, the United States had and continues to have the most active markets in the world. U.S. citizens wanted to improve the quality of their lives and were willing to work hard and buy the new products rolling off the production lines. But, by the 1960's, in the absence of strong competition, productivity began to level off and manufacturers failed to invest in new production plants and equipment. A new breed of corporate managers, skilled in financial management, infiltrated the upper echelons of corporations. These managers did not rise from the ranks and knew little about the mechanics of designing and manufacturing products. Few had the experience earned by serving in the design rooms and the factories. Their loyalty to the corporation was based more on quarterly profits for the stockholders and their own stock holdings than long-term corporate growth and customer satisfaction. The corporation became a short-term stepping stone along a career path instead of an enterprise to be further developed over the years.

In many manufacturing sectors, there was no urgency to invest in research and development. Products were selling; therefore, it was difficult to justify the need for engineers in a laboratory or model shop. There was little product development because the U.S. had its market to itself without serious "outside competition". Investing in new plant and equipment implied great risk and as long as sales volume increased as the population and economy grew, there was little justification to jeopardize the "return on investment" (ROI).

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[1] Hearing, *Automobile Development and Production*, by U.S. House of Representatives, Technology Policy Task Force, Committee on Science, Space, and Technology, October 1, 1987. Testimony of Mr. David Halberstam, Author, "The Reckoning".

The unions interpreted increases in sales volume and higher corporate earnings as justification for more lucrative labor contracts. (Increases in wages and other benefits were not always warranted by increases in production.) Their short-range view and their lack of concern for a threat from competition made management reluctant to fight the demands of unions. It was easier to raise prices and, if necessary, relax quality standards.

Machine tools and manufacturing facilities were allowed to age without replacement. Tools and facilities were expensive and hard to justify to a stockholder looking for a bigger dividend. It was easy for management to put investment decisions off year after year. When one steel company executive was asked why he was going to Germany to buy steel, he offered, ". . . their steel was cheaper and of higher quality". When asked why, he answered, "because we weren't bombed in World War II".

Federal and state governments contributed to these problems by establishing barriers to growth in manufacturing. By the 1970's new government agencies were formed and staffed to implement countless controls and restrictions. These controls were implemented in areas such as consumer safety, employee working conditions, environmental protection and product liability. Higher manufacturing costs resulted in two ways. First changes in manufacturing processes in response to government controls were expensive and rarely improved productivity. Second, projects that would have resulted in the construction of new manufacturing plants were delayed while their acceptance by the public was debated.

All of these factors resulted in a serious erosion of United States manufacturing capabilities. Now, it is estimated that 70 percent of current U.S. manufacturing output faces direct foreign competition.[2]

Manufacturing employment in the United States dropped from its peak of 21 million workers in 1979 to 18.4 million in 1983. Since that time it has grown back to 19.5 million workers.[3] Manufacturing's share of the GNP has remained relatively constant, however.

Our image around the world, as our manufacturing position eroded, was damaged.

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[2] *The Technological Dimensions of International Competitiveness*, A Report to the Council of the National Academy of Engineering, Prepared by the Committee on Technology Issues that Impact International Competitiveness, chaired by W. Dale Compton and George E. Solomon, Washington, D.C., 1988.

[3] "The Productivity Paradox," Special Report, *Business Week*, June 6, 1988.

> Nowadays, America is compared to a sick and ill-humored uncle who is suffering from financial and family problems, paying no attention to chastity or discipline.[4]
>
> Increasingly, "Made in America" means junk. It means what "Made in Japan" did in the United States years ago. . . .[5]

Status of Manufacturing

Between 1981 and 1986 the U.S. went from a positive trade balance of $6 billion to a deficit of $141 billion. Of the $147 billion change, $135 billion was due to a decline in manufactured goods.

In 1960 manufacturing accounted for 31 percent of U.S. employment; in 1985 manufacturing accounted for 20 percent of U.S. employment. The reasons for the decline in employment included shifts from industries with a high ratio of labor to product value to industries with a lower labor factor. But, the decline was also a result of increases in productivity in certain industries. Between 1950 and 1986 the contribution of the manufacturing sector to U.S. GNP—measured in constant dollars—has fluctuated around 22 percent. While the overall share of manufacturing in gross national product has not decreased, it certainly is true that some of America's export industries have encountered serious problems. Lynn Williams, President of the United Steel Workers of America, notes: "If you take the military piece out of it and leave the commercial piece . . . then you get a much clearer picture of how we are deindustrializing in terms of our ability to compete in this global economy and to really produce goods. . . ." [6] But, even in the case of products for defense, the U.S. buys many components from overseas; products that include ball bearings, resins, electronics, etc. Current U.S. exports of military equipment average approximately $12 billion yearly.

Analysts present evidence to show that America's competitive position in high technology trade may be "quite narrow and fragile." Stephen S. Cohen and John Zysman of the University of California at Berkeley conclude: "In the early eighties the range of high-technology sectors from which a surplus was generated was actually quite narrow: aircraft, computers, and agricultural chemicals. The overall high-tech surplus disappeared by 1983, and in 1984 and 1985 high technology, too, ran a growing deficit." [7]

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[4] "Confident Japanese See United States in Serious Decline," *Washington Post*, July 3, 1988, Quote attributed to Yukio Matsuyama, Editorial Chairman of Japan's prestigious Asahi Shimbun newspaper.

[5] Ibid. Quote attributed to John Stern, Head Tokyo Office of the U.S. Electronics Industry Association.

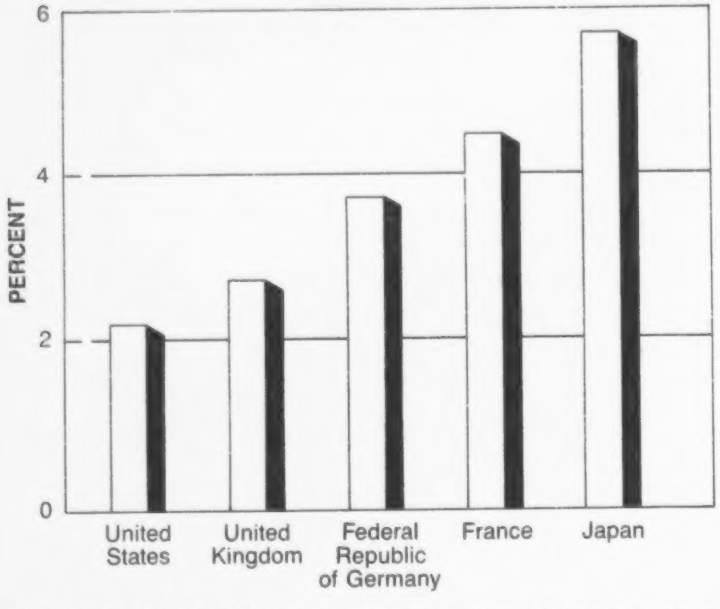
[6] Hearing before the Technology Policy Task Force of the Committee on Science, Space, and Technology, 100th Congress, First Session, July 1, 1987 (No. 32), *The Effects of Technological Change on the Labor Force*, p. 123.

Productivity increases provide economic growth without cost. When productivity increases wages, profits, and return on investment can all increase without any increase in consumer costs. United States productivity in manufacturing, measured in output per labor hour, is high in absolute value but has been falling relative to our competitors. As shown in Figure 1, *productivity improvements* in U.S. manufacturing were less than Japan, France, and other European competitors.[8] Nations such as Korea and Taiwan are also making larger gains in productivity than the U.S.

Average annual percentage change in manufacturing productivity output per hour in selected countries between 1973 and 1985.

CHART E-1A

AVERAGE ANNUAL PERCENTAGE CHANGE IN MANUFACTURING PRODUCTIVITY OUTPUT PER HOUR IN SELECTED COUNTRIES BETWEEN 1973 AND 1985.



(Source: The Technological Dimensions of International Competitiveness; National Academy of Engineering, p. 21.)

For whatever reason, American productivity increases have not kept pace with manufacturing industries in other nations. At one time, this was supposedly due to the very low productivity and outdated facilities in other countries who had to "catch-up". Supposedly these other nations would therefore show larger productivity increases because they were so unproductive to begin with. But now, comparisons of goods produced indicate otherwise.

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[7] Cohen, Stephen S. and Zysman, John. *The Myth of a Post-Industrial Economy, Technology Review*, February/March 1987, pp. 59-62.

[8] *The Technological Dimensions of International Competitiveness*, A Report to the Council of the National Academy of Engineering, prepared by the Committee on Technology Issues that Impact International Competitiveness, co-chaired by W. Dale Compton and George E. Solomon.

Thurow claims that much of the productivity problem of U.S. industry is due to an excess of white collar workers who contribute to corporate overhead.[9]

> About 40 percent of the cost advantage of producing a car in Japan, for example, can be traced to lower white-collar overheads. Foreign firms such as the Japanese auto companies have shown that they can operate plants in the United States with much smaller white-collar staffs than their American counterparts. The problem stems from the U.S. philosophy of management, which holds that the best manager is the one who has the most information and makes the most decisions. Events and underlings must be monitored on a day-by-day, if not minute-by-minute, basis. Middle level managers spend more time reporting than they do managing.[10]

An increasing fraction of American industry managers are spending the majority of their time performing nonproductive administrative tasks rather than managing. Over-administered and under-managed industries or government will ultimately experience diminished productivity.

During the period between 1973 and 1979 U.S. productivity growth averaged 1.4 percent. As a result of efforts to streamline, downsize, merge, and utilize the latest manufacturing technologies, U.S. manufacturing productivity has been increased to an average growth of 3.5 percent in the 1980's. Productivity growth peaked above 5 percent in 1983 but dropped back down to a level near 3 percent. Many are concerned that much of the manufacturing productivity increase in this decade has come from trimming fat from labor and is therefore a "onetime shot". Automation has cut direct labor costs on manufactured goods to between 8 percent and 12 percent of total production costs on the average. Electronics manufacturing direct labor costs are only between 4 percent and 6 percent of electronics production costs. Further labor reductions can do little to improve productivity.[11]

As Lester Thurow points out:

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[9] Lester C. Thurow, Dean MIT Sloan School of Management, "Pruning Our White-Collar Ranks: A Key To Productivity", *Technology Review*, November/December, 1985.

[10] Ibid.

[11] "The Productivity Paradox: Why the Payoff From Automation is Still So Elusive—And What Corporate America Can Do About It," Special Report *Business Week*, June 6, 1988.

> Japanese auto companies seem to require just about half as much labor as their U.S. counterparts to produce the same output. Inside the United States the best Japanese assembly facilities require slightly less labor than the best U.S. assembly facilities and far less labor than the worst U.S. plants.[12]

These data suggest that the differences in manufacturing performance between Japanese and American industry are more likely due to management and facilities rather than labor.

Productivity is one measure of performance; however, quality is another. When it comes to the quality of products, the United States lags behind. In 1985, the best high precision U.S. robots had the ability to place something within 25 micrometers of where it belonged. The best Japanese robots had an accuracy of 5 micrometers. U.S. robots also had more down time for repairs. Quality indicators show that imported cars consistently dominate domestically produced cars. In a comparison of the quality of Japanese and U.S. air conditioners, the failure rates for the worst producers, all U.S., were 500 to 1000 times as great as those made by the best producers, all Japanese. The average U.S. manufacturer suffered 70 times as many assembly-line defects and made 17 times as many service calls in the first year of services as others. When it comes to high technology steels, U.S. firms cannot roll steel with the corrosion resistance, mechanical properties and dimensional tolerances found in top-of-the-line foreign facilities. American nuclear reactors suffer 5.5 emergency shutdowns per year, whereas the average Japanese reactor has only 0.3 shutdowns per year. America, of course, still leads in some industries, such as aircraft production, but more and more often it lags behind.[13]

Mr. Phil M. Condit, Executive Vice President, Boeing Commercial Airplane Company testified before the Task Force at a Hearing on November 4, 1987. He gave the following account of a transaxle.[14]

The Ford Motor Company designed a transaxle, (a combination transmission and front wheel drive) and later discovered that the demand for it exceeded Ford's production capability. Since Ford owns part of Mazda, they sent the drawings and specifications to Japan to have them build a quantity of transaxles. Later after a number of these parts failed in service, Ford investigated the matter and soon learned that the failed units were made in the U.S.A. Those made in Japan had consistently got better customer ratings.

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[12] Lester C. Thurow, "A Weakness in Process Technology," *Science*, Volume 238, December 18, 1987.

[13] Ibid.

[14] "Corporate Giants and Global Competition: Dynamos or Dinosaurs," Hearing before the Technology Policy Task Force of the Committee on Science, Space, and Technology, U.S. House of Representatives, Nov. 4, 1987.

Ford took six Japanese units, disassembled them and made measurements of various parts, especially the concentricity of the bore in a number of piston housings. It was learned that the Japanese units were made to closer tolerances even though they were made from the same drawings and specifications.

It was observed that U.S. management and labor generally "builds to spec", meaning that if a component meets the requirements specified on the drawings and specifications, it is "good enough" and is accepted by Quality Control. But, in a Japanese plant, each person who contributes to manufacturing a component takes pride in his/her work and tries to make it "better than the specifications".

As stated previously in this policy report, the Task Force did not have the resources to examine many industries. Consequently, the manufacturing industries of automobiles, electronics, aerospace, and steel, because of their great importance to the economic well-being of the United States, are briefly discussed.

Automobile Industry

Automobiles are the most expensive purchases Americans make in their lifetime. If the average person purchased 10 cars in his/her lifetime, the total cost would be as much as a house. Furthermore, automobiles are virtually expendable while houses keep their value.

Worldwide there are 175 automobile manufacturers that are producing about 45 million cars, trucks, and buses each year. Total worldwide annual automobile sales are approximately $385 billion. Automobile production is third to agriculture and electronics in terms of world sales.[15]

Fortune Magazine has tabulated the world's top 20 automobiles. Their data are shown in Table 1.[16]

TABLE 1.—1986 WORLD AUTO SALES

Automaker	World market share (percent)	Number of units (millions)	10-year growth rate (percent)
1. General Motors (US)	18.1	8.16	−1.0
2. Ford (US)	13.3	5.98	−0.9
3. Toyota (Japan)	8.2	3.69	+3.1
4. Volkswagen (W. Germany)	6.1	2.76	+7.2

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[15] "Who's Ahead in the World Auto War," *Fortune*, November 9, 1987.

[16] Ibid.

TABLE 1.—1986 WORLD AUTO SALES—Continued

Automaker	World market share (percent)	Number of units (millions)	10-year growth rate (percent)
5. Nissan (Japan)	6.0	2.70	+0.77
6. Chrysler (US)	4.9	2.20	−0.6
7. Peugeot (France)	3.8	1.72	+8.2
8. Honda (Japan)	3.5	1.58	+9.0
9. Renault (France)	3.5	1.57	+1.2
10. Fiat (Italy)	3.3	1.48	+2.3
11. Mazda (Japan)	3.1	1.41	−1.5
12. Mitsubishi (Japan)	2.8	1.27	+5.0
13. Lada (USSR)	2.4	1.10	−1.5
14. Suzuki (Japan)	2.0	0.91	+14.1
15. Subaru (Japan)	1.4	0.63	+10.1
16. Daihatsu (Japan)	1.3	0.59	+6.4
17. Daimler-Benz (W. Germany)	1.3	0.59	+0.13
18. Isuzu (Japan)	1.2	0.53	+4.5
19. Rover Group (Britain)	1.0	0.47	−1.2
20. BMW (W. Germany)	1.0	0.45	+4.5

These data illustrate that U.S. auto manufacturers remain first and second in terms of world market share but several Japanese firms have noteworthy gains. Nine Japanese manufacturers are listed in the top 20 while there are 3 U.S. and 3 West German manufacturers listed in the top 20. Of alarm to U.S. manufacturers is the fact that all three of the U.S. firms have had negative growth over the last 10 years, while 8 of the 9 Japanese manufacturers have had positive growth. (Many believe that the fierce competition of Japanese firms for Japan's domestic market has prompted their surge in growth. This competition has prepared them well for international competition.)

The University of Michigan Transportation Research Institute predicts that by 1995 General Motors will produce fewer autos, Ford and Chrysler will have small gains, but Toyota, Nissan, and Honda will undergo dramatic growth, with Honda's growth predicted to be 55 percent.[17]

> The U.S. automobile industry was threatened and is still challenged by Japanese producers whose manufacturing practices are often more efficient and whose products are of high quality, and by new manufacturers in less devel-

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[17] Ibid.

oped nations that have the further advantage of extremely low-cost labor.[18]

Table 2 includes data on imports and exports of automotive and related commodities. Not only do imports of passenger motor vehicles exceed exports by almost $43 billion, there are huge differences in parts categories, trucks, and tires.

TABLE 2.—PASSENGER MOTOR VEHICLES, TRUCKS, TRACTORS, AND PARTS IMPORTS AND EXPORTS IN 1987

[In billions of dollars]

Commodity category	1987 import value	Import ranking by category	1987 export value	Export ranking by category
Passenger motor vehicles	49.9	1	7.1	7
Parts of motor vehicles and handling equipment	13.1	3		Below 50
Internal combustion engines and parts	4.5	21	4.3	15
Trucks and special purpose motor vehicles	8.3	8	2.5	27
Parts of internal combustion engines non-specific	3.5	29		Below 50
Tires and tubes	2.4	47		Below 50
Parts of road vehicles and tractors		Below 50	11.2	2

Data compiled by Congressioal Research Service from official statistics of the U.S. Department of Commerce.

Ford Motor Company of Europe has been a success (they rank third in European sales) and has generally been more innovative than domestic automobile companies. Ford was quicker to employ an electrolysis rustproofing undercoating process in Europe than in the United States. The highly competitive European market is the likely reason for this.[19]

The rest of the world has gasoline prices about twice those of the United States. In general, citizens of European countries and Japan are less inclined to take lengthy automobile trips than U.S. citizens. These two factors plus the fact that Americans are taller, heavier, and more concerned with personal comfort have made Americans much more inclined, in comparison to the rest of the world, to purchase large, fuel inefficient automobiles that are loaded with extras. U.S. car manufacturers emphasis on the highly profitable U.S. market for big cars has helped make them noncompetitive in the international market.

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[18] *The Technological Dimensions of International Competitiveness*, A Report to the Council of the National Academy of Engineering, Prepared by the Committee on Technology Issues that Impact International Competitiveness, chaired by W. Dale Compton and George E. Solomon, 1988.

[19] Hearing, "Automobile Development and Production," conducted by the Technology Policy Task Force, U.S. House of Representatives, Committee on Science, Space, and Technology, October 1, 1987. Testimony by Mr. David Halberstam, Author "The Reckoning".

U.S. car manufacturers' decision to not place emphasis on the fuel efficient, small car market was largely motivated by the low profit potential of this end of the automobile market. The slogan in the early '80s was "small cars, small profits". However, it left this segment of the market ripe for Japan and later South Korea to take over with well-engineered, high quality automobiles. Thus, American automobile manufacturers essentially gave Japan and other countries the market they needed to justify establishing elaborate marketing networks. Having made this step, there is no reason to believe that these countries will remain content with the small car market.

To effectively compete with international manufacturers, U.S. auto manufacturers must emphasize making design changes that improve the quality of their product and they must learn how to rapidly implement these improvements.

> I think in the automobile industry, among other things, we got very fascinated with what I will call cosmetic improvements—How should it look? What was the design style? Not with, did it work well? How do I improve it? We went along for a long time with a defect rate that was very consistent among the three U.S. automobile manufacturers. Suddenly the Japanese appeared (with a defect rate) at about one-third that level. And what did the consumer see, a product that worked. It ran. You climbed in it and you didn't worry every time you turned the key—it ran. Its maintenance levels were low. And so I think you have to really differentiate on improvements. Have I made the product better? . . . The other issue is the speed with which improvements are made. If you make true product improvements quickly, you have an advantage.[20]

Thurow has also pointed out the slowness of the U.S. automobile industry.

> American auto companies require 62 months from inception to delivery of a new car; Japanese companies only 43 months.[21]

Even if the American auto industry had a one and one-half year jump on the design of a new concept for an automobile, the Japanese could still be the first to deliver. Of more importance is the advantage this shorter cycle period offers the Japanese in implementing their own design improvement concepts.

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[20] Corporate Giants and Global Competition: Dynamos or Dinosaurs?,"Hearing before the Technology Policy Task Force of the Committee on Science, Space, and Technology, U.S. House of Representatives, Nov. 4, 1987.

[21] Lester C. Thurow, "A Weakness in Process Technology," *Science*, December 18, 1987.

If the United States were to implement an oil import tariff or fee, the increase in fuel costs would promote interest of the U.S. consumer in purchasing small, fuel-efficient automobiles. The shorter development-manufacturing cycle of the Japanese would give them a tremendous advantage over American automobile manufacturers in meeting the shifting market demands of the U.S. consumer. Therefore, with the present extended design-manufacturing cycle of the U.S. automobile, an oil import tariff would likely further aggravate our trade imbalance.

Aerospace Industry

The U.S. Aerospace Industry has maintained its competitiveness through the years of decline of the U.S. automobile industry. The Aerospace Industry includes aircraft, aircraft engines, engine parts, aircraft equipment, guided missiles, space vehicles, space propulsion units and parts, and space vehicle equipment. There was $102.9 billion in total U.S. built shipments made in 1987. Aircraft accounted for 72% of these shipments, while guided missiles and space sectors accounted for 28% of the business.[22]

According to U.S. Department of Commerce (DOC) statistics for 1987, the top ranked U.S. exports were aircraft, spacecraft and associated equipment with exports totaling $17 billion. DOC import figures show that we imported $4.5 billion worth of goods in this category.[23] This difference at $12.5 billion has been in the $11–12 billion range since 1985.

The United States has held the lead in the development of commercial aircraft since the 1950s, after the loss of the German aircraft industry in World War II and the downturn in the British aircraft industry following the war.

As did many U.S. industries in the 1930s and 1940s, the Aerospace Industry depended largely upon the transfer of technology from foreign sources to the United States. As Phil Condit, Executive Vice President of Boeing Commercial Airplane Company said,

> When we at Boeing look back on our history, we see that our success has come less from our own development of new basic technologies, and more from our ability to put to practical use technologies developed by others. Our success in jet transport aircraft began when we adopted jet engine

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[22] *U.S. Industrial Outlook*, 1988, Section on Aerospace, Page 39-1.

[23] Data compiled by Congressional Research Service from U.S. Department of Commerce statistics.

technology developed by the British and swept-wing technology brought home from postwar Germany and put them to use in the Boeing 707.[24]

Several features distinguish commercial aerospace technology from other areas of manufacturing. Investment in developing a new product is measured in billions of dollars, aircraft purchase cost is measured in tens to hundreds of millions, total production numbers of successful products are measured in hundreds and thousands, and production lifetime of product is measured in tens of years.

According to Congressman Mineta, when the Boeing 747 was first released in 1969 it sold for $22 million dollars (1969 dollars).[25] Mr. Condit explained that today's improved version of the Boeing 747 sells for between 100 and 120 million dollars each (1988 dollars). To date 747 total production stands at 700 in comparison to 1,800 units for the Boeing 727 and 2,000 units for the Boeing 737. Mr. Condit further related that the 747 is expected to have a product life cycle of 70 years where life cycles are measured from start of the first design until the last plane is taken out of service.[26]

Like other areas of successful U.S. manufacturing industries, commercial aircraft development is based on incremental improvement or cyclic development rather than a "ladder development" as would come from great leaps in science. Mr. Condit explained to the Task Force that today's version of the 747 is 45 percent more fuel efficient than the first units built by Boeing. A version to be released in 1989 will have an all digital electronic system in comparison to the all analog systems of early models.[27]

World market demand and the available supply for both military and commercial aircraft has a substantial impact on the U.S. economy. Consequently, it is imperative that the U.S. maintain its leadership in this industry.

According to the National Academy of Engineering, the U.S. commercial aircraft industry is challenged in world markets by foreign producers who received massive design, development, and production subsidies from their governments. Market penetration by aircraft companies in their countries has been the goal of numerous foreign governments.[28]

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[24] Corporate Giants and Global Competition: Dynamos or Dinosaurs?," Hearing before the Technology Policy Task Force of the Committee on Science, Space, and Technology, House of Representatives, November 4, 1987, Testimony of Mr. Philip M. Condit, Executive Vice President, Boeing Commercial Airplane Company.

[25] Ibid., testimony by Congressman Norman Y. Mineta.

[26] Ibid., Testimony by Mr. Philip M. Condit.

[27] Ibid.

The U.S. can expect to lose orders for aircraft if other nations continue with their plans to develop their own advanced military and commercial aircraft. On the military side, other nations are anxious to build their own military aircraft. Japan's Mitsubishi Industries has plans for their FSX fighter, an upgraded F-16. Britain, West Germany, Belgium, Italy and Spain are considering the heavier rough-weather EFA fighter. France will want to go ahead with the Rafale. India, who already builds MIGs is planning a light aircraft of their own design and Brazil has joined with Italy in the AMX project.

American aerospace companies have not yet built a fleet of advanced commercial aircraft in the 50 to 100-seat capacity range, a supersonic transport, an aircraft with the advanced features of the Airbus 320, or a hydrogen fueled airplane. This may be the result of conscious business decisions which, in the case of the supersonic transport, on a sales/profit basis, was appropriate. But, if these decisions mark a trend, the U.S. could lose its preeminence and competitive advantage in the long run.

Of concern in the future of U.S. commercial aircraft is the Airbus Industries, a consortium of aerospace firms that are either owned by or financed by the governments of France, West Germany, Great Britain, and Spain. This consortium has been successful in the design and production of commercial transport aircraft. This subject is being tested in GATT discussions. Congressman Mineta expressed the opinion that Airbus Industrie is making airplanes as an employment policy and parking them until they can be sold or some disposition taken.[29]

The Task Force believes close cooperation between NASA and aerospace companies should continue in order to maintain the strength of the U.S. aerospace industry. Work on such programs as the Advanced Turboprop Propulsion System by NASA led to the further development by the General Electric Company of a propulsion system that can now operate with a 40% savings in fuel consumption. A similar arrangement could be productive in developing hydrogen fueled aircraft for future use should oil shortages or environmental conditions create a market pull.

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[28] "The Technological Dimensions of International Competitiveness," A Report to the Council of the National Academy of Engineering, Prepared by the Committee on Technology Issues that Impact International Competitiveness, cochaired by W. Dale Compton and George E. Solomon.

[29] "Corporate Giants and Global Competition: Dynamos or Dinosaurs?," Hearing before the Technology Policy Task Force of the Committee on Science, Space, and Technology, House of Representatives, November 4, 1987. Testimony of Congressman Norman Y. Mineta.

Steel Industry

During World War II the U.S. steel industry increased capacity in response to the U.S. and allies need for war materials. By 1950, the U.S. supplied almost 50 percent of the world's steel production; Japan provided 3 percent. Between 1951 and 1960 the American steel industry, under pressure from the Federal Government, raised steel production capacity from 105 to 136 million tons per year despite the fact that demand was weak.[30] By 1977 U.S. steel production capacity peaked at 160 million tons/year.[31]

By the 1980's, many U.S. companies experienced severe problems caused by overbuilt steel producing capacity; high labor costs; inefficient plants and equipment; new domestic competition from smaller, more efficient mini-steel mills; decline in steel demand; development of foreign steel industries; and alternative materials that could be used in place of steel. As a result large reductions in personnel as well as large financial losses occurred throughout the domestic industry. Meanwhile iron and steel mills imports have grown to a net trade deficit in 1987 of $8.4 billion. Average annual U.S. employment in the blast furnaces and basic steel products industries declined from 560,000 in 1978 to 275.000 in 1986.[32] Bethlehem Steel Corporation, the U.S. third largest steel company with an annual raw steel production of about 10.5 million tons (12 percent of domestic production) realized a decline in employment from 94,500 in 1978 to 37,500 in 1986. In 1982 alone, Bethlehem Steel lost almost $1.5 billion.[33]

Although total domestic steel consumption was approximately 100 million tons/year for the past 5 years, domestic steel shipments have declined from 88 million tons in 1981 to 70 million tons in 1986.[34] The industry is operating at below 50 percent of its 1977 peak capacity.

Steel imports, excluding semi-finished steel, increased from 16 percent of the domestic steel market in 1980 to a

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[30] "New Technology and the Future of Steel," Hearing before the Subcommittee on Investigations and Oversight and the Subcommittee on Science, Research, and Technology of the Committee on Science and Technology, U.S. House of Representatives, July 22, 1985. Testimony of Dr. David Cantor, Congressional Research Service.

[31] "Steel Initiative," Hearing before the Subcommittee on Energy Development and Applications and the Subcommittee on Science, Research, and Technology of the Committee on Science and Technology, U.S. House of Representatives, July 17, 1985. Testimony of Frank Luerssen, Chairman, Inland Steel Company.

[32] "The Technological Dimensions of International Competitiveness," A report to the Council of the National Academy of Engineering, Prepared by the Committee on Technology Issues that Impact International Competitiveness, 1988.

[33] Memorandum dated September 18, 1987, from Marshall R. Mazer, Manager Governmental Programs, Bethlehem Steel Corporation, to Ronald E. Williams, Study Director Technology Task Force.

[34] Ibid.

> record high of 26 percent of the domestic steel market in 1984. Imports of steel mill products, excluding semi-finished steel, captured 22 percent of the domestic market in 1986 and an estimated 21 percent in the first six months of 1987. During 1986, the first full year in which Voluntary Restraint Agreements have been in place under the President's Steel Program to control steel imports, steel imports were three percentage points, or about 2.6 million tons, over the 18.5 percent target established by the program. Unless renewed or extended, the Voluntary Restraint Agreements are scheduled to expire on September 30, 1989.[35]

To improve the competitiveness of the U.S. steel industry several improvements need to be made. Short-term impact would best come through the development of improved control and sensing systems that would provide better product quality and reduce product cost by reducing labor costs. (Labor accounts for about 25 percent of steel production costs.) Second, production systems have to be improved with the goal of eliminating one or more steps in a processing sequence. Research should focus on the development of new steelmaking processes that would allow domestic steel producers to "leapfrog" foreign producers.

In 1986 Congress approved a continuing resolution providing $7.5 million for a research and development initiative at DOE's Oak Ridge National Laboratory and Argonne National Laboratory for development of new technologies to significantly increase the energy efficiency of processes that produce steel. (Energy costs are about 25 percent of steel production costs.) Congress required that industry contribute funds equal to 30 percent of the government's contribution.

Comparisons of manufacturing costs for steel prepared by Paine Webber, Inc., lead to the conclusion that foreign governments are subsidizing their steel industries. The analyses, shown in Table III, show that the U.S. steel industry is price competitive in terms of cost of building product. Yet foreign manufactured materials are increasing their share of the domestic market.

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[35] Ibid.

TABLE 3.—COMPARISON OF STEEL PRODUCTION COSTS OF UNITED STATES, CANADA, WEST GERMANY, AND JAPAN

[Cost in U.S. $/net ton of hot rolled products]

	United States	Canada	West Germany	Japan
Share of 1986 U.S. imports (percent)		19.7	12.4	27.2
Labor cost	77	72	68	65
Material cost	191	168	202	182
Taxes	6	5	3	9
Depreciation	19	21	29	55
Interest	10	13	13	50
Cost of transport to United States		20	59	64
Total cost to reach United States	303	298	374	426

These data suggest that either some foreign suppliers are absorbing steel production costs in order to continue exporting steel to the U.S. market or their quality is better than that of U.S. products.

Electronics Industry

The world's electronics industry has become a major economic force and is second only to agriculture in size. The American Electronics Association defines the electronics industry to include: (1) companies that manufacture electronic equipment or systems, (2) companies that provide electronic research and development services, and (3) companies that develop and sell software for computer users. Other electronics services companies, such as telephone companies, for example, are not included. It is the largest manufacturing area employing 13.3 percent of the manufacturing work force. Annual worldwide sales in electronics are estimated to be $550 billion.[36] By 1990 worldwide electronics sales are expected to exceed $600 billion with $65 billion attributed to the consumption of semiconductors.[37] In 1987 electronics industries located in the U.S. produced products valued at $256 billion. U.S. owned worldwide electronic industry corporations had sales of $370 billion.[38]

Table 4 illustrates how sales in 6 major areas were distributed among the major producers around the world.

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[36] Estimate provided by Harry Lewenstein, Manager Industry Statistics, American Electronics Association.

[37] Globalization of Technology, Proceedings of the Sixth Convocation of the Council of Academies of Engineering and Technological Sciences, J.H. Muroyama and H.G. Stever, Editors, National Academy Press, 1988, page 45.

[38] Data provided by Harry Lewenstein, Manager, Industry Statistics, American Electronics Association.

TABLE 4.—WORLDWIDE PRODUCTION OF ELECTRONICS EQUIPMENT IN 1985

[Value given in billions of U.S. dollars]

Industry	United States	Western Europe	Japan	Rest of world	Total
Data processing	80.4	21.2	17.3	9.9	128.8
Communications	28.6	17.7	7.5	4.6	58.4
Industrial	34.9	17.8	9.5	4.3	66.5
Consumer	16.2	10.1	36.1	12.4	74.8
Military	48.2	11.0		1.0	61.2
Transportation	8.5	2.0	2.8	3.0	16.3
Total	217.8	79.8	73.2	35.2	406.0

With the exception of consumer electronics (the second largest segment of the electronics industry) the United States produced 50 percent or more of the electronics equipment built in 1985.

Electronics sales data from U.S. factories are shown in Table 5 for the year 1980 to 1987. Despite the steady growth in shipments from U.S. factories over this period, since 1983 U.S. imports of electronics have exceeded exports.

TABLE 5.—SALES, PAYROLL, AND EMPLOYMENT OF U.S. ELECTRONICS FACTORIES COMPARED TO IMPORTS AND EXPORT SALES FOR THE YEARS 1980–87

Year	Year end employment (millions)	Annual payroll (billions)	Sales dollars per employee	Shipments from U.S. factories (billions)	U.S. exports (billions)	U.S. imports (billions)
1980	1.97	$35.1	$64,467	$127	$22.8	$15.5
1981	2.05	39.8	71,220	146	25.3	19.3
1982	2.23	48.8	75,336	168	26.0	21.0
1983	2.38	55.7	78,992	188	27.9	26.7
1984	2.59	64.6	86,873	225	32.8	39.0
1985	2.54	69.3	93,307	237	35.6	44.5
1986	2.47	71.6	97,166	240	38.1	51.2
1987	2.54	77.6	100,787	256	45.2	57.9

Data provided by Harry Lewenstein, Manager, Industry Statistics, American Electronics Association.

Export sales from the World's seven largest exporters are listed in Table 6. Export sales to the United States are also shown. Note that although Germany, the United Kingdom, and France are major exporters, they are exporting very little to the United States.

TABLE 6.—COMPARISON OF ELECTRONICS EXPORTS FROM LEADING EXPORTERS OUTSIDE THE UNITED STATES AND LISTING OF THEIR EXPORTS TO THE UNITED STATES

Country	Total exports (billions)			Exports to United States (billions)		
	1984	1985	1986	1984	1985	1986
Japan	$34.1	$33.6	$43.6	$15.9	$15.4	$19.3
Germany	10.4	11.6	16.9	0.8	0.9	1.2
United Kingdom	7.1	8.1	9.0	0.8	0.9	1.0
Taiwan	5.2	5.1	7.6	3.1	2.8	3.9
Korea	5.0	4.0	6.4	3.4	2.3	3.4
Singapore	5.1	4.9	6.2	2.5	2.5	3.1
France	5.4	6.2	7.7	0.4	0.5	0.5

Data provided by Harry Lewenstein, Manager, Industry Statistics, American Electronics Association. Compiled from Steward Trade Data.

U.S. import and export data for electronics are shown in Table 7. This table illustrates that imports and exports from the U.S. are reasonably well balanced except for consumer electronics areas: phonographs, TV image equipment, AM and FM radios, television receivers, sound reproduction equipment, etc.

TABLE 7.—COMPARISON OF U.S. IMPORTS AND EXPORTS FOR 1987 ELECTRONIC EQUIPMENT SALES

Commodity	Export value (billions)	Import value (billions)
Parts for office machines and automatic data processing machines	$10.1	$9.2
Automatic data processing machines and auxiliary equipment	9.3	7.3
Electronic Components and Parts	7.7	8.3
Measuring and checking instruments	6.1	3.2
Telecommunications equipment	4.8	8.8
Electromedical and radiological apparatus	1.7	
Phonographs, T.V. image, and sound reproduction equipment		5.6
AM and AM/FM radios		4.4
Office machines		2.5
Television receivers and combinations		2.5

Data compiled by Congressional Research Service from official statistics of the U.S. Department of Commerce. Those entries for which data are not listed were ranked below 50 on the import and export listings.

Loss of the consumer electronics business is especially disconcerting when one recognizes that the U.S. was the unparalleled world leader in consumer electronics manufacturing after Thomas Edison's invention of the phonograph in 1887. We held this leadership position until the early 1970's. Today the U.S. market share is less than 5 percent.[39]

Discussion of High Definition Television

Of the consumer electronics areas, the one which has received the most immediate attention by the Congress is high definition television (HDTV). Technically, high definition television offers significantly improved clarity compared to current TV. But, closely related to this technology is the future use of home receivers for two-way person-to-person communications and retail transactions. Groups in several countries have been working to develop systems which can be used in the production of dramatically improved television pictures and sound transmission. It is estimated that the market for these new HDTV products could be as high as $144 billion over the next 20 years.[40] Some suggest that the HDTV market will be $25 to 30 billion annually by the year 2000.[41] With 89 million television households (83 percent served by cable) the U.S. will be a major market for HDTV.

HDTV is likely to involve much more than just improved TV quality through transmission and display of additional lines of video on a television screen.[42] The ultimate market is Home Information Systems in which home computers are integrated with HDTV.[43] HDTV encompasses several new features for the expanded use of television: (1) higher quality audio and video; (2) increased options for personal use such as two-way person-to-person video and audio communication with linkage to teaching institutions, provision for retail transactions, and electronic mail; and (3) computer interfacing with extensive data bases.

> The HDTV market represents a complete merging of technologies essential to the domination of the consumer electronics market and major portions of the telecommunications and computer markets. The nation which becomes the key supplier of production, distribution, and receiving equipment within the HDTV markets will have developed a principal means to control a major portion of the semi-

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[39] "High Definition TV (HDTV), "Hearing before the Subcommittee on Science, Research and Technology of the House of Representatives, Science, Space, and Technology Committee, Testimony of Pat Hill Hubbard, Vice President, Education, Science and Technology Policy of American Electronics Association, June 23, 1988.

[40] "Economic Potential of Advanced Television Products", Report by Larry F. Darby, Darby Associates for National Telecommunications and Information Administration, April 7, 1988.

[41] "High Definition TV (HDTV)," Hearing before the Subcommittee on Science, Research, and technology of the House of Representatives Science, Space, and Technology Committee, Testimony of Richard J. Elkins, Chairman, Prometrix Corporation, June 23, 1988.

[42] Ibid., Testimony of Professor N. Russel Neuman, MIT.

[43] Ibid., Testimony of Paul Hill Hubbard, American Electronics Association.

> conductor chip and equipment business and therefore, have achieved a significant step toward total technological superiority in the years to come.
>
> If the United States does not ultimately become a major, if not predominant supplier of products to the HDTV marketplace, the resulting change in technological leadership will have an extraordinarily negative effect on our standard of living, political and economic leadership, military preparedness and the general control of our destiny as a nation.[44]

Development of the integrated circuit technology required for HDTV (microprocessors, high-density memories, video amplifiers in GaAs technology, etc.) as well as flat screen displays, and opto electronics/photonics will provide the developing country with the foundation to make revolutionary improvements in radars, video tape recorders, television display systems, related camera equipment, and magnetic tape. Thus, other applications of the technology required for HDTV are likely to have as big if not bigger market than HDTV systems. Failure to develop HDTV will produce a ripple effect throughout the U.S. electronics industry and directly effect national security.[45] At stake are the data processing, communications, and consumer electronics markets whose world-wide annual sales already exceed $300 billion.

The Congress is also being asked to deal with the issues of standards for HDTV. Should these standards favor cable television or free public television? Should they favor U.S. built HDTV? Robert C. Wright, NBC, recommends that advanced TV transmission be compatible with today's TV receivers. He also recommends adopting a single 6 megahertz channel standard as well as formation of a consensus between government and industry on a uniform standard applicable to all electronic media.[46] Richard D. Roberts emphasized that it was the view of the cable television industry that setting a single government standard for advanced TV would be premature.[47] Lawrence A. Tisch explained that CBS does not support the recommendation by an FCC Advisory Committee that the FCC allocate the spectrum needed to implement a full HDTV broadcast system.[48]

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[44] Ibid., Testimony of Richard J. Elkus, Jr., Chairman, Prometrix Corporation.

[45] Ibid., Testimony of Pat Hill Hubbard, American Electronics Association.

[46] "Impact of Advanced Televison technologies on Diversity and Localism "Hearing before the Subcommittee on Telecommunications and Finance of the U.S. House of Representatives Committee on Energy and Commerce, Testimony of Robert C. Wright, President and CEO, National Broadcasting System, National Broadcasting System, June 23, 1988.

[47] Ibid., Testimony of Richard D. Roberts, President and CEO of Telecable.

[48] Ibid., Testimony of Lawrence A. Tisch, President and CEO, CBS, Inc.

Congressman Mel Levine summarized the status of HDTV in the United States by pointing out:

> The hour is late for HDTV. Foreign firms already have a huge lead in developing HDTV and if Zenith's consumer electronics division is sold to a foreign firm, there will no longer be a U.S. owned manufacturer of television sets. . . . If foreign competitors like NEC . . . seize control of HDTV, they are far more likely to ask their own chip divisions to develop new customized chips for it rather than ask an Intel or National Semiconductor to do so. U.S. firms could mount a concerted effort to catch up with international competitors in developing HDTV, with appropriate help from the public sector. Such an effort would require that the private sector take the initiative, but also that our government extend it the same support as foreign companies enjoy from their government—including matching grants, relaxation of antitrust rules, research and development support, and full FCC cooperation.[49]

Discussion of Semiconductors

Semiconductors are the building blocks from which all electronics systems are built. Many Americans are coming to understand the role of semiconductors in assuring America's economic future. Mr. Richard J. Elkus, Jr. expressed an accurate view of this.

> An item fundamental to almost anything we make, buy, or sell is the semiconductor device. I suggest that the nation which controls the development and production of semiconductor devices and equipment will have achieved a major step toward technological domination and economic and political leadership in the world.[50]

Mr. Elkus pointed out that the Japanese semiconductor industry and the U.S. semiconductor industry have been driven by contrasting goals. The U.S. has directed management, technical resources, and capital toward the development of specific integrated circuits with the goal of establishing profit centers. The Japanese have directed these same resources toward the goal of achieving domination of end use markets that use integrated circuits.[51] In so doing, the Japanese have built the three largest semiconductor vendors in the world—NEC, Hitachi, and Toshiba.

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[49] "High Definition TV (HDTV)," Hearing before the Subcommittee on Science, Research, and Technology, of the House of Representatives Science, Space, and Technology Committee, June 23, 1988, Testimony of Congressman Mel Levine.

[50] Ibid., Testimony of Mr. Richard J. Elkus, Jr., Chairman Prometrix Corporation.

[51] Ibid.

The U.S. semiconductor industry consists of captive producers, who produce only for their own internal consumption as well as merchant and niche producers who sell their products to other companies.[52] Sales data for captive contractors are not available. However, it is estimated that captive producers typically manufacture about one third of the total U.S. output. IBM, the U.S. largest semiconductor manufacturer, accounts for about 55 percent of all semiconductors produced by captive firms.[53]

The world semiconductor market has grown rapidly and is expected to continue its growth. Past data and expectations for the future are shown in Table 8. It is expected that shipments will grow at an annual rate of 14 percent.

TABLE 8.—TOTAL WORLDWIDE SEMICONDUCTOR MARKET TABLE

[In billions of dollars]

Year	Semiconductor Shipments ($ Billion)
1980	14.1
1985	21.8
1986	26.9
1987	32
1990	47.5

The semiconductor market is dominated by integrated circuits whose sales make up nearly 80 percent of the market. In 1985 Japan based companies sold 40 percent of the semiconductor devices sold worldwide. U.S. based companies sold 49.5 percent. In 1986 Japan based companies sold 46 percent of the market, while U.S. firms sold 42.5 percent. Between 1980 and 1990 it is predicted that Japan will increase semiconductor sales by a factor of 5.5; the U.S. will increase semiconductor sales by a factor of 2.5; while the rest of the world will increase their sales by a factor of 9.[54]

In addition to loss of worldwide market, U.S. chip manufacturers have been unable to achieve their share of Japan's chip market negotiated in the U.S.-Japan Semiconductor Trade Agreement of 1986. Under the terms of this agreement, U.S. chipmakers were to have received a 20 percent share of Japan's chip market. U.S. firms have only a 9.8 percent of this market even though the agreement was made two years ago.[55]

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[52] "The Benefits and Risks of Federal Funding for Sematech," Congressional Budget Office, September 1987.

[53] "Semiconductor Industry Statistics, Analysis and Economic Trends—Past and Future," Mr. Jack Beedle, President In-Stat, Inc., January 1987.

[54] Ibid.

Perhaps more important than losses in market share are the U.S. industry's loss of technical leadership. The long-range implications of this could be severe. In most aspects of process technology and manufacturing the U.S. has lost its lead to Japan and Japan has been widening its lead. U.S. industry retains a lead in product design and computer aided design and engineering, but the Japanese industry is gaining ground there as well.

Causes for U.S. loss of market share are: (1) Growth of Japan's electronics industry has exceeded growth of U.S. electronics industry especially in consumer electronics. This growth created a market and fostered rapid growth in Japan's semiconductor industry.[56] (2) The real value of the dollar in yen between 1980 and 1985 promoted Japanese electronics exports. (3) Japanese companies sold dynamic memory chips in Japan and the U.S. at prices below their manufacturing costs. (This practice is consistent with Japan's emphasis on capturing market share.) (4) Japanese technology, particularly manufacturing process technology has improved rapidly giving them technical advantages in advanced integrated circuits.[57]

There are many reasons for the U.S. loss of technical leadership: (1) Japan invests a higher portion of revenues in research and development with heavy emphasis on research and development of manufacturing technology. (2) Japan invests a higher portion of revenues in plant and equipment. (3) Japan's government sponsorship and national telephone company sponsorship of semiconductor research and development has emphasized commercial applications while the U.S. has emphasized defense. (4) Japan has encouraged organized research and development collaboration among their semiconductor firms and equipment suppliers to a much greater extent than the U.S.[58]

Two advantages that Japan has gained will present great difficulties for the U.S. in the future.

1. Japan's domination of high volume production of Dynamic Random Access Memorys (DRAMs) provides them with the ideal vehicle to perfect their manufacturing process and maximize yields. None of the chip areas in which the U.S. exerts technical leadership provides an equivalent opportunity.[59]

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[55] Semiconductor Industry Association News Release, Tokyo, June 3, 1988.

[56] "The Semiconductor Industry," Report of a Federal Interagency Staff Working Group, November 16, 1987.

[57] Ibid.

[58] Ibid.

[59] Ibid.

2. U.S. industries that supply manufacturing materials and manufacturing equipment for semiconductors have fallen way behind Japanese components. Investment in advanced production equipment has dropped because of loss in market share.[60]

The U.S. semiconductor industry's concern for deterioration in manufacturing equipment growth has led to the creation of SEMA TECH, a joint effort between government and the private sector to reverse the slide in America's leading role in world semiconductor technology, and to maintain U.S. leadership in "state-of-the-art" defense.

Analysis of Manufacturing Problems

A careful analysis of the causes behind problems in U.S. manufacturing is needed to arrive at a set of policy recommendations that can serve the purpose of improving America's competitiveness in manufacturing.

The prime reason for America's poor productivity, quality, and trade performance is easily isolated. When it comes to process technologies Americans are slow to invent and slow to adopt. In industry after industry, if one plots the speed with which new process technologies are first adopted and the speed with which they are put in place, U.S. firms lag behind foreign firms.[61]

Quality

Quality improvement is a critical feature in advancing the competitiveness of products manufactured in the U.S. A survey of 600 United States business executives reveals that 80 percent of them believe that quality plays the most important role in improving the competitive position of U.S. industrial companies. Sixty percent of automobile customers rate trouble-free performance or quality as the most important attribute of automobiles.[62]

Americans seem strangely uninterested in improving the quality of their processes. In one study of German and American companies, the Germans spent 8 to 12 percent of their annual sales on plant and equipment to enhance the quality of their manufacturing performance. Their U.S. counterparts spent two to three times less and then primarily to expand capacity or cut costs. Japan has outspent the U.S. two to one on automation in the past 5 years and a much higher fraction of its new machine tools (55 versus 18 percent) were computer controlled.[63]

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[60] Ibid.

[61] Lester C. Thurow, "A Weakness in Process Technology," *Science*, Volume 238, December 18, 1987.

[62] "The Technological Dimensions of International Competitiveness," A Report to the Council of the National Academy of Engineering, Prepared by the Committee on Technology Issues that Impact International Competitiveness, chaired by W. Compton and G. Solomon, 1988.

W. Edwards Deming, after years of disinterest by U.S. industry, took his message abroad and taught the Japanese how to produce goods of high quality at low cost.

Deming has known for a quarter century that unless Americans changed their approach to quality and productivity, the economy would be destroyed. And he has had to endure the ultimate curse: no one has listened.[64]

Deming's 14 points on creating quality products are really directed at improving the management of manufacturing. *Quality is the result.*

DEMING'S 14 POINTS

1. Create consistency and continuity of purpose.
2. Refuse to allow commonly accepted levels of delay for mistakes, defective material, defective workmanship.
3. Eliminate the need for dependence upon mass inspection.
4. Reduce the number of suppliers. Buy on statistical evidence, not price.
5. Search continually for problems in the system and seek ways to improve it.
6. Institute modern methods of training, using statistics.
7. Focus supervision on helping people to do a better job. Provide the tools and techniques for people to have pride of workmanship.
8. Eliminate fear. Encourage two-way communication.
9. Break down barriers between departments. Encourage problem solving through teamwork.
10. Eliminate the use of numerical goals, slogans, posters for the workforce.
11. Use statistical methods for continuing improvement of quality and productivity and eliminate all standards prescribing numerical quotas.
12. Remove barriers to pride of workmanship.
13. Institute a vigorous program of education and training to keep people abreast of new developments in materials, methods, and technologies.
14. Clearly define management's permanent commitment to quality and productivity.[65]

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[63] Lester C. Thurow, "A Weakness in Process Technology," *Science*, Volume 238, December 18, 1987.

[64] *Mechanical Engineering*, "Deming's Way," Myron Tribus, Director AKT Systems and Energy Company Founder and Director, American Quality and Productivity Institute, Haywood, CA. January 1988.

[65] Ibid.

Implementation of Deming's and other quality experts' principles have had dramatic effects on companies market share because not only has quality of products been improved, but productivity has improved, manufacturing costs have decreased and overall manufacturing management has improved.

> The Eastman Chemicals Division started the implementation of quality management concepts as a result of losing market share in a major product during the 1970's. The strategy that was used to regain the market share focused on improving quality of products as well as improving the quality of managing our processes. The result of this effort allowed us to regain our market share position but, more importantly, demonstrated that focusing on improving quality also yields improvements in productivity and reductions in manufacturing costs. Our successful experience in the application of quality management concepts resulted in a massive management led project to implement quality management concepts in every aspect of managing the Eastman Chemicals Division.[66]

Cost Reductions

In view of the fact that reducing waste and inefficiency and other labor saving measures can contribute very little to further reductions in manufacturing costs, the attention of cost analysts have turned to other avenues. Among these are: (1) improved control over the flow of materials in factories to reduce flow time and reduce inventories, (2) better worker management, (3) improved equipment and processing techniques, and (4) improved corporate structure including new accounting methods and rules.

Development Cycle Speed

The speed of the manufacturing and development cycle is extremely important. Far more vital than being the first to market is the need to make frequent and rapid product improvements and offer these improved products to the consumer on a steady basis.

> The company with the shorter cycle for development and manufacturing will appear to have newer products with newer technologies. It is the speed of the manufacturing and development cycle that appears as technical innova-

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[66] "The Cutting Edge," Hearing before the Investigations Subcommittee of the Science, Space, and Technology, House of Representatives, June 20, 1988. Testimony by Francis W. Jackson, Director, Quality Management Planning, Eastman Chemicals Division of Eastman Kodak Company.

> tion or leadership. And it only takes a few turns of that cycle to build a commanding product lead.
>
> A key factor in the speed of the cycle, as well as in its quality and cost, is the relationship between development and manufacturing. Design for manufacturability results in a rapid start-up of production. Close ties between manufacturing and development also translate into early knowledge of technical problems, into speed of introduction, and into better quality and lower cost. And the lack of these ties does the opposite.[67]

Some U.S. companies are learning to shorten their development cycle. A few years ago, Xerox Corp. executives were stunned to learn that Japanese competitors were developing new copier models twice as fast as Xerox and at half the cost. Its market share eroding, Xerox faced a painful choice: either slash its traditional four- to five-year product development cycle or be overtaken by more nimble competitors.

Today, after a sweeping reorganization and millions of dollars of investment, Xerox can produce a new copier in two years. But that still isn't as fast as some of its Japanese competitors, who have also quickened their pace. "We'll be 30% more efficient by 1990," promises Wayland Hicks, Xerox Executive Vice President.[68]

Liability

Aircraft manufacturers are frequently held responsible for aircraft accidents. The cost of their liability insurance is passed on to consumers. The cost of aircraft built by Piper Aircraft includes $75,000 worth of liability insurance and legal fees. Some of Piper's small aircraft can be built for less money than the cost of their liability price tag. In the 1978-79 time frame 18,000 piston aircraft were built each year. Now about 1,000 are built each year. This decrease in sales is principally due to the cost of liability insurance.[69]

In many cases product liability can last for the entire life of a product. It isn't unusual for elevator manufacturers to be sued for minor injuries arising from tripping on unleveled elevators even 70 years after the elevator was introduced into service.

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[67] "Corporate Giants and Global Competition: Dynamos or Dinosaurs," Hearing before the Technology Policy Task Force of the Committee on Science, Space, and Technology, House of Representatives, November 4, 1987. Testimony of Dr. Ralph E. Gomory, Senior Vice President for Science and Technology, International Business Machines Corporation.

[68] *Wall Street Journal*, "Speeding Up: Manufacturers Strive To Slice Time Needed To Develop Products," John Bussey and Douglas R. Sease, Reporters for The Wall Street Journal, p. 1.

[69] Philip H. Abelson, "Product Liability in a Litigious Society," *Science Magazine*, June 17, 1987.

The costs of defending against product liability suits are so high that corporations are willing to settle suits out of court that they could likely win in the courtroom. In one instance a company estimated that it had a 98 percent chance of winning a liability suit, but the defense would cost betweeen $3 million and $5 million. They settled out of court for $200,000.

Dow Chemical with domestic sales of $6 billion spent $100 million on legal fees and liability insurance in the United States in 1987. The same year their foreign sales were $7 billion, but their legal fees and liability insurance costs were $20 million. In 1987 Dow Chemical was the defendant in 456 suits in the United States and 4 suits outside the United States.[70]

Integrated Manufacturing Systems

In the new industrial revolution—the information revolution—taking place in manufacturing, capital consists of information technologies that require a commitment on the part of employees. Employees are now responsible for entire manufacturing systems rather than just simple, narrow tasks.[71] One feature of computer integrated manufacturing (CIM) systems is just-in-time purchasing systems that allow for more efficient use of capital by holding inventories to only those levels needed to meet short-term production.

Mr. Laurence C. Siefert, Vice President of Engineering, Manufacturing and Production Planning, AT&T, explained AT&T's use of CIM.[72]

The first step to improving productivity is to use manufacturing systems engineering to redesign and re-engineer the manufacturing process. Today's computer technology permits analysis tools to be employed to characterize, simulate, and predict the performance of manufacturing processes prior to deployment of capital facilities.

The second step is computer integrated manufacturing or mechanization of information flow. In this step information on product flow, processing steps, and quality analysis are intergrated in a computer so that real-time process controls can be implemented by production engineers and manufacturing efficiency can be maximized. The third step is to install automation equipment but only when (1) the discipline, control, or feedback goes beyond what humans would normally do—superhuman processing and (2) there is satisfaction with product design and information system design.

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[70] E.P. McGuire, "The Impacts of Product Liability," The Conference Board, N.Y., 1988.

[71] "Productivity: Why It's the No. 1 Underachiever," Special Report, *Business Week*, April 20, 1987.

[72] "Communications and Computers in the 21st Century," Hearing before the Technology Policy Task Force of the Committee on Science, Space, and Technology, House of Representatives, June 25, 1987, Testimony of Mr. Laurence C. Siefert, Vice President of Engineering, Manufacturing, and Production Planning, AT&T.

For years many have believed that the secret to manufacturing productivity was identifying products for high volume production (economy of scale), optimizing the design of the product and the design of the manufacturing process, freezing all processes and "cranking out" product. Change was unacceptable. However, things are changing. Product life cycles are being shortened to times as short as months. The flexibility that can be built into CIM systems has promoted the growth of factories that can do short production runs and still be cost effective. These are called Flexible Computer Integrated Manufacturing (FCIM) Systems. These systems can be shared by a wide range of products, they can be shared by multiple manufacturers, or they can rapidly (through software changes) respond to changes in product design. The name of the game in manufacturing has become, not to just give the customer his or her own personalized design, but at the price and availability of mass produced items.[73]

> Shared flexible computer integrated manufacturing (FCIM) facilities now are being developed by consortia of small businesses. These FCIM "micro-factories" have much extended lives, since a given facility can be continually reprogrammed to make new or modified products, but still retain some of the economics of scale of a dedicated plant. High levels of reproducibility and quality control also can result for production runs of as few as a thousand of a kind as needed for just-in-time delivery.[74]

Investment

There are many ways industry can invest to strengthen its future in manufacturing. We have discussed the role of computer integrated manufacturing in strengthening the future of manufacturing. Measures of investment in plant and equipment are means to determine how well industry is positioned for the future. Data comparing U.S. investment in this area to other nations are shown in Chart E-1B. Under-investment in plant and equipment has contributed to the U.S. loss of competitiveness.

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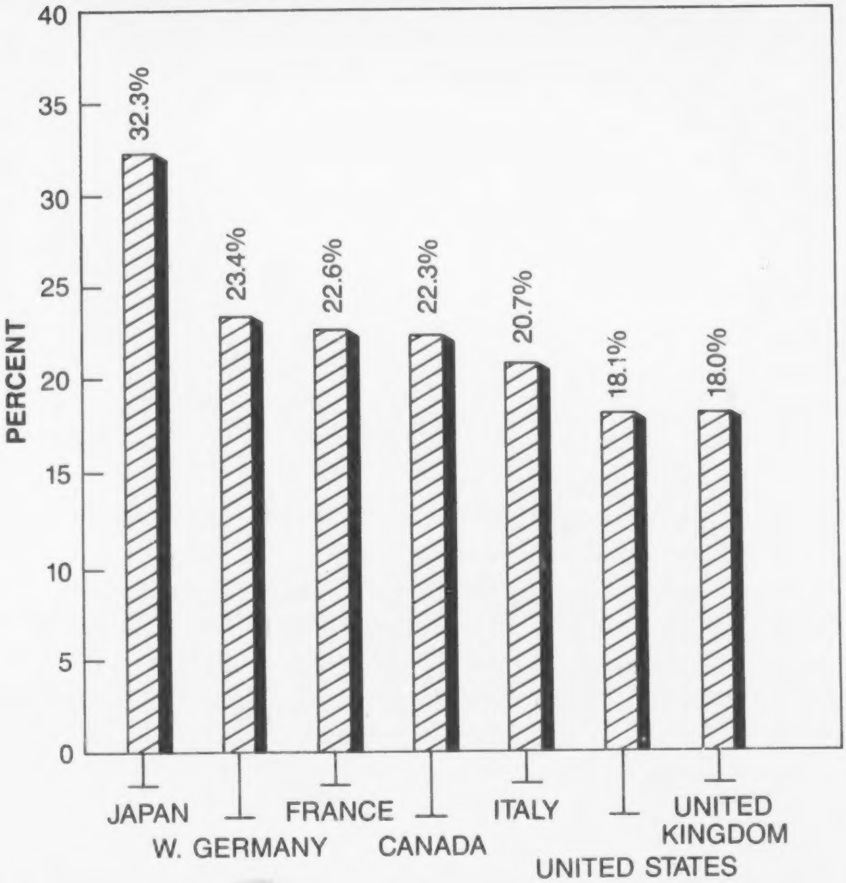
[73] "Factory of the Future, *The Economist*, May 30, 1987.

[74] "The FCIM—Micro Factory: Flexible Computer Integrated Manufacturing," U.S. Department of Commerce, Office of Productivity, Technology, and Innovation, March 1988.

CHART E-1B

PERCENT OF GROSS DOMESTIC PRODUCT INVESTED ANNUALLY IN PLANTS AND EQUIPMENT BETWEEN 1960 AND 1982[75]



Percent of Gross Domestic Product Invested Annually in Plants and Equipment Between 1960 and 1982 [75]

Another area of investment that is equal to equipment and plant investment in terms of importance is investment in research and development. In Table 9 we compare U.S. 1986 research and development expenditures as a percent of sales for several industrial products. Note the heavy investment that electronics-related firms are making.

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[75] OECD, "Historical Statistics, 1960–1982".

TABLE 9.—1986 RESEARCH AND INVESTMENT EXPENDITURES AS A PERCENT OF SALES [76]

[Industry and research and development as a percent of sales]

Semiconductors	12.2
Computers	8.3
Drugs	7.8
Software/Services	7.7
Peripherals	7.0
Instruments	6.7
Leisure Industries	5.9
Telecommunications	5.1
Office Equipment	4.8
Aerospace	4.5
Electronics	4.4
Chemicals	4.1
Automotive	3.7
Electrical	3.3
Machinery (Tools, industry, mining)	3.3
Oil Service/Supply	3.3
Machinery (Farm, construction)	3.0
Miscellaneous Manufacturing	2.8
Personal and House Products	2.6
Tire and Rubber	2.6
Conglomerates	2.6
Automotive Parts	2.4

Despite the high U.S. investment in semiconductor research and development, the Japanese have consistently since the mid-1970's invested 15% of their sales in research and development.[77]

The third area of investment that is critical to manufacturing industries is investment in human resources. This subject is treated in another section of this report.

CONCLUSIONS

While fewer people are employed in manufacturing than in services, the burden of correcting the trade deficit lies squarely on the shoulders of U.S. manufacturing industries.

The U.S. market is larger than that of any other nation. If U.S. industry can recapture a larger share of that market, the trade deficit can be reduced. To accomplish this, representatives from industry should advise the Congress about the government policies that would provide the proper incentive to encourage industry to make more products at home.

U.S. industry should significantly increase its foreign marketing efforts, modernize production facilities, and improve the quality of its products.

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[76] T.R. Howell, W.A. Noellert, J.H. MacLaughlin, and A.W. Wolff, "The Microelectronics Race—The Impact of Government Policy on International Competition," Westview Press, 1988.

[77] Ibid.

U.S. industry should increase its investments in research, development, and manufacturing processes to levels equivalent to or above its most advanced competitors. In the Recommendations section of this report, the Task Force recommends major government, sponsored initiatives in consumer electronics, manufacturing engineering, and management education.

CHAPTER 2—SERVICES

ISSUES

With 80 percent of the workforce, over 90 million people, working in service industries, the United States clearly has shifted from a manufacturing economy to a service-based economy. This shift has important implications for public policies with respect to employment and trade.

DISCUSSION

The United States currently has a high level of employment compared to most other industrialized nations. Forty-seven out of every 100 Americans are employed. According to Peter F. Drucker of the Claremont Graduate School, America's lack of planning may have contributed to its success in creating jobs. He notes that entrepreneurship and innovation must occur "way down and close to the events" and therefore are inconsistent with central planning.

> . . . the new businesses of the entrepreneurial economy create new jobs, as has been happening in the United States during the last ten years (which explains why the massive unemployment in the old "smokestack industries" has caused so little political trouble so far in the United States and has not even triggered a massive protectionism reaction). But even if an entrepreneurial economy creates the new jobs, there is need for organized efforts to train and place the redundant former "smokestack" workers—they cannot do it by themselves.
>
> . . . Planning as the term is commonly understood is actually incompatible with an entrepreneurial society and economy. Innovation does indeed need to be purposeful and entrepreneurship has to be managed. But innovation, almost by definition, has to be decentralized, ad hoc, autonomous, specific, and micro-economic. It had better start small, tentative, flexible. Indeed, the opportunities for innovation are found, on the whole, only way down and close to events. They are not to be found in the massive aggre-

> gates with which the planner deals of necessity, but in the deviations therefrom. . . .[1]

Fifty percent of our Gross National Product (GNP), over two trillion dollars annually, comes from the service sector. There also have been early indications that the service sector is no more vulnerable to a recession than is the manufacturing sector. On the other hand, the service sector may not be a safeguard against a weak economy.

Approximately 30 million people, more than all the people employed in manufacturing work in retail shops and eating establishments.

> Actually, over 92% of those 30 million are part-year or part-time workers, many with second jobs. They are threatened as consumption dips. . . .[2]

A number of these services are in the luxury category. Travel, motel/hotel, entertainment, and restaurants are among the areas which could realize sudden business declines as family disposable income shrinks. Even medical services, which entail burdensome costs for many families, are likely to be reduced in a recession.

Contribution of Technology to Service Industries

The service sector includes the following professions and business.

Commercial Uses of Space
Data Processing Services
Computer Professional Services
Electronic Data Base Services
Videotex Services
Research and Development Services
Commercial Banking
Savings Institutions
Venture Capital
Insurance
Mutual Fund Industry
Equipment Leasing
Health and Medical Services
Transportation Services
Merchant Wholesaling
Distribution Services
Retail Trade
International Trading Systems
Franchising
Advertising
Hotels and Motels
Travel Services
Entertainment
Educational Services
Legal Services
Management Consulting and Public Relations Services
Operations and Maintenance Services*

**1988 U.S. Industrial Outlook*, U.S. Department of Commerce, January 1988.

These services can be combined into the following subsectors: Producer Services, Distributive Services, Social Services, Personal Services, and Communication and Transportation.

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[1] Drucker, Peter F. *Innovation and Entrepreneurship: Practice and Principles*, New York, Harper & Row, 1985, pp. 253-260.

[2] *The Economist*, February 6, 1988, pp. 15-16.

New technologies have contributed to the expansion of services by providing the capability to perform new services and by accelerating the growth of existing services. Most of the credit can be attributed to the high levels of investment in information technology. But advanced production technology in the manufacturing sector and communication-computing technology in services have been the "drivers." Telecommunications, information, and banking are especially technology intensive and will continue to undergo major changes. Two major service industries are telecommunications with 1988 revenues of over $140 billion and information processing services with 1988 sales expected to reach: $32 billion in computer professional services; $12 billion in systems integration earnings; $10 billion in computer consulting and training services; and $10 billion in custom programming services.

The convergence of technologies has reduced the differences between the data processing and telecommunication services and is leading to shared service markets and shared customers. Improvements in telecommunication services have resulted from technological advancements in remotely distributed processors, computers, image transmitting machines, software, voice message systems, integrated voice-data workstations, microwave components, satellites, optical fibers, optoelectronics, digital switching networks, and all areas of microelectronics. Many of these same technologies, with the addition of copying machines and intelligent terminals, also have made a significant contribution to information services.

Introduction of these technologies into home information centers is expected during the 1990s. These centers will have high definition television technology integrated with computers, VCRs, stereo equipment, and two-way communication. Thus, a single system will permit electronic mailing, home banking, bill paying, securities brokerage, household accounting, shopping, education, and entertainment to be done at the home. This technology may displace many jobs in the services industry.

Shifts from Manufacturing to Service Industries

Between 1976 and 1982, the U.S. had the largest gain in service employment among the Organization for Economic Cooperation and Development (OECD) nations and Japan. The U.S. had 41% of its employment growth in social and personal services compared to Japan's 13%, while Japan's growth of 46% in producer-oriented services can be compared to only 24% in the U.S.

Overall, however, the transition from manufacturing to services has been a long-term trend in all industrialized nations.

> The process of economic development is often referred to as industrialization, but judged by employment patterns it

> could be more accurately described as a transition to services. Even during the early period of U.S. industrialization, for example, employment in services increased as rapidly as employment in goods-producing industries.
>
> This shift will continue in the next decade. According to U.S. Department of Labor projections in 1995, 74.4 percent of the American labor force will produce services (compared with 72.3 percent in 1984) while only 17.2 percent will be employed in manufacturing. . . .
>
> A concern exists that the reduced role for manufacturing in the economy will threaten national well-being . . . Manufacturing, some argue, is a vital source of productivity growth of middle-class incomes and the demand for capital goods.
>
> The U.S. experience indicates that these arguments seriously misinterpret the evidence. First, increases in services production have not come at the expense of goods production . . . Second, the declining employment share of goods production primarily results from the relatively faster increases in output per worker in goods industries. Just as rising farm productivity increased food production while freeing farm labor for employment in factories, so relatively rapid growth in manufacturing productivity is increasing goods production while making a larger share of the labor force available for employment in services . . ."
>
> Third, the stylized image of structural change in the United States is represented by the displaced steel or automobile worker forced to take a menial job in fast foods or electronic assembly . . . Even sophisticated analysts believe that, as the economy shifts away from basic manufacturing and toward high-technology and service industries, the number of mid-level jobs will decline . . . But . . . these presumptions . . . are [not] correct. One cannot get an accurate picture of structural change by looking at just a few sectors or relying on anecdotal evidence. The auto and steel industries have received a lot of attention, but even at their 1979 peaks, they accounted for only 1.1 percent of total employment.[3]

It is important to distinguish between shifts to service industries resulting from rising productivity in manufacturing and those which stem from "abandoning production to others".

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[3] Hearing before the Technology Policy Task Force of the Committee on Science, Space, and Technology, "The Effects of Technological Change on the Labor Force", July 1, 1988.

Most celebrations of the shift from industry to services construct a parallel to the shift from agriculture to industry. According to that argument, the shift from low-productivity, low-paid farm labor to higher-productivity, hence higher-paid employment in industry is precisely what economic development is about. The same developmental movement, the same "creative destruction" is now being repeated in the shift out of industry and into services and high tech.

This view of economic history, although familiar and reassuring, is misleading. It confuses two separate transitions: a shift out of agricultural production and a shift of labor out of agriculture.

The first shift never occurred. U.S. agricultural production did not go offshore or shrivel up. To the embarrassment of those who view the cultivation of large quantities of soybeans, tomatoes, and corn as incompatible with a high-tech future, agriculture has sustained the highest long-term productivity of any sector of the economy. We automated agriculture; we did not send it offshore or shift out of it. As a result we developed massive quantities of high-valued-added, high-paid jobs in related industries and services such as agricultural machinery and chemicals. These industries and services owe their development, scale, and survival to a broad and strong American agricultural sector. . . .

. . . Insisting that a shift to services or high technology is "natural" is irresponsible analysis and perverse policy. The competitiveness of the U.S. economy—the ability to maintain high and rising wages—is not likely to be enhanced by abandoning production to others. Instead of ceding production, public policy should actively aim to convert low-productivity, low-wage, low-skill production processes into high-technology, high-skill, high-wage activities—whether they are included in the manufacturing unit itself or counted largely as services firms.

America's declining competitiveness is troubling precisely because emerging fundamental changes in production technologies and the extent and forms of international competition are likely to prove enduring. The international heirarchy of wealth and power is being reshuffled, and it is happening fast and now.[4]

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[4] Cohen, Stephen S. and Zysman, John, "The Myth of a Post-Industrial Economy", *Technology Review*, pp. 55–56, 58–59, 62.

The Balance of Trade in Services

The collection and analysis of more accurate data pertaining to service industries is needed to help develop informed government policies with respect to trade in the service sector. The Office of Technology Assessment, in its 1986 report, questioned errors and omissions in the official data on the service sector citing:

1. Lack of Data. The government collects data on 10,000 categories of goods but only 40 categories of services.
2. Incomplete coverage. The service account omits many service transactions that take place in non-service industries. Many transactions are private and, therefore, not included. Some survey forms for collecting data are voluntary and therefore not returned.
3. Difficulty of assigning prices. Price evaluation of certain services is difficult and data are subject to wide differences in interpretation.

While the data may not be as precise as it should be, there is evidence the United States has been experiencing a trade surplus in services in contrast to the huge deficit in goods.

The Office of Technology Assessment (OTA) estimates that U.S. exports of services were between 69 billion dollars and 91 billion dollars in 1984. These figures are much higher than the 43.8 billion estimated by the Department of Commerce, Bureau of Economic Analysis.

> . . . even though trade in services will remain small compared with trade in goods, the services are of considerable importance internationally. In some cases—e.g., engineering and construction contracts—exports of goods may follow ;from sales of services. In other cases, American service firms have followed American manufacturers overseas. High-technology goods exports, almost by definition, embody high service content in forms such as engineering or other professional knowledge. Linkages between overseas sales of goods and services, already strong, will grow as American companies seek new international business strategies, approaching their markets in global rather than national terms.[5]

There are two generally accepted categories of trade: trade in goods (merchandise), and other non-goods transactions or invisibles. The invisibles portion of the current account is sometimes referred to as the "services account". This services account is further divided into "factors," meaning income on holdings abroad, such as dividends, interest, and wages paid to U.S. labor by foreign companies and nonfactor services, such as travel, tourism, business, and professional services. This distinction is important because of the negative balance in the "factor account" which is a result of the U.S. becoming a debtor nation.

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[5] Office of Technology Assessment, *Trade in Services: Exports and Foreign Revenues*, Summary, Washington, D.C., September 1876, pp. 13–14.

In round numbers, in 1986, the U.S. ran a $50 billion deficit in goods and a $22 billion surplus in factor and nonfactor services. But, of this $22 billion surplus, the nonfactor portion was only $3 billion. The other $19 billion in factors fluctuates with shifts in international investment flows and is, therefore, highly variable and relatively dependent on our deficits.[6]

In addition, even though most of our workforce is engaged in services, trade in services is small compared with trade in goods. According to OTA estimates, services account for about one-quarter of U.S. exports.[7]

America's strength in service exports is in international transportation. Transportation of U.S. goods abroad on U.S. aircraft or ships and ticket sales to foreign travelers account for approximately 30% of U.S. trade in services.

The U.S. also is strong in data processing and computer services. Gary Fernandes, Chairman of Electronic Data Systems, a subsidiary of General Motors, believes business will grow 20% each year as foreign multinationals try to untangle and integrate their worldwide telecommunications and data processings networks.[8]

Software producers, led by Ashton-Tate, Loftus Development, and Microsoft, already derive anywhere from 20% to more than 40% from overseas sales. Fifteen of the world's 20 biggest software companies are American.

Other services range from housekeeping to environmental services. For example, Service Master of Downers Grove, Illinois, launched over 500 home cleaning franchises in Japan and does housekeeping for 40 hospitals. Hospital Corporation of America owns 28 hospitals abroad. Waste Management of Oak Brook, Illinois has operations in Argentina, Saudi Arabia, and Australia. Above all, environmental protection services, worldwide, are expected to become a major market in the years ahead as the citizens of other nations, particularly in Asia, demand a cleaner environment. Most of these services are carried out by the citizens of the country in which they are performed; the trade balance gains are mostly in the factors account.

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[6] Ibid.

[7] *International Competition in Services*, Congressional Summary, Congress of the United States, Office of Technology Assessment.

[8] Ibid.

Furthermore, technology associated with trade in services can be expected to transfer rapidly to entrepreneurs in the host countries, just as it has in the past in services such as shipping. As world trade in services expands, the U.S. may well find itself holding a somewhat smaller share of a much bigger pie, according to *Fortune* Magazine.

International Competition in Services

Although OTA estimates that services account for about one-fourth of American exports—higher than the 17 percent indicated in official government statistics—John Alic, Senior Associate at OTA, cautions:

> While the United States runs a positive balance of trade in almost all services with almost all regions of the world, this may not continue. OTA's assessment points to competitive threats in services much like those we have seen over the past 15 years in manufacturing. It will become more difficult to export services, even in the absence of trade barriers.[9]
>
> "Japan has launched a second export wave, this time in services" says Harry Freeman, an executive vice president at American Express. Last December the Harvard Business Review ran a much noted article that asked, "Will Services Follow Manufacturing Into Decline?" The article concluded that it can happen here. Less tentatively, Business Week flatly declared a few weeks back that "America is losing its edge in selling services overseas." [10]

Financial Services

Among national banking industries, only the Japanese have mounted a real threat to the United States in financial services. Japanese banks followed Japanese manufacturing firms onto the world stage. Japan now can claim most of the biggest banks in the world, as measured by assets. The speed with which Japanese financial institutions turn new opportunities into competitive reality—and the magnitude of the competitive threat to U.S. banks—depends first of all on the speed of deregulation in Japan's domestic financial markets. The faster Japan's Government liberalizes at home, the freer Japanese banks will be to compete overseas.

While U.S. financial service firms have been moving into overseas markets, foreign banks have moved into the United States. In both retail and commercial banking, some foreign banks will be quite successful in the United States, but this in itself should not be taken as a sign of flagging U.S. competitiveness. It is, rather, a natural consequence of an open and attractive market, *with fewer regulatory restrictions than in the past.* Foreign banks come here in part because of the size of U.S. markets, in part because their corporate clients have invested in the United States, in part because they seek experience in a deregulated and highly competitive environment.

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[9] Hearing before the Task Force on Technology Policy, Committee on Science, Space, and Technology, 100th Congress, First Session, October 22, 1987 (No. 66) "Technology and Economics in a Shrinking World", p. 21.

[10] Richard J. Kirkland, Jr., *Fortune Magazine*, June 8, 1987, page 33.

The Future of Telecommunications and Software Services

Rapid progress in automated software development could lead to shifts in international competitive standing. So could unexpected success in foreign projects such as Japan's fifth-generation effort. But the more likely outcomes of future competition will be gradual slippage in the U.S. position, particularly as foreign software firms move away from custom programming. Specially tailored software is expensive, and no longer a good solution to many customer needs. Cost pressures will drive countries like Japan toward the standardized applications packages pioneered by American suppliers.

The next generation of telecommunications technologies—Integrated Services Digital Networks, or ISDN—will provide end-to-end digital communications for voice, data, and in some cases video signals. New services—e.g., computer networks—will be cheaper; eventually, any home or office that now has a telephone should be able to tap an information utility with a very broad array of available services. With different firms and different governments beginning to implement ISDN, the U.S. government will face continuing decisions in international forums concerning technical standards, as well as questions of domestic regulatory policy. Given the tight control exercised by PTTs (post, telegraph, and telephone authorities, generally functioning as government monopolies) in many countries, negotiations over issues such as TBDFs and the international implementation of ISDN will probably go on for years. The costs of incompatibility in ISDN standards could be high, while the interests of equipment suppliers and user groups may differ substantially.

Productivity of Service Industries

The productivity of American service industries also can be expected to affect our balance of trade. While manufacturing productivity has increased, productivity in the service sector—which accounts for 80 percent of what the United States produces—is down. This decrease is contrary to conventional wisdom, which assumes greater productivity, and fewer jobs, with increasing computerization. Indeed, according to some observers, just the opposite has occurred. Service industries have provided a growing number of jobs, in part because they are inefficient. Although computer technology has the potential for improving the productivity of service workers, as Paul A. Straussmann, Retired Vice President of the Xerox Corporation, notes: "Computers will not make a badly managed business better. The expenses for computerization and the increased rigidity in computer-managed procedures are likely to accelerate the decline of incompetent management. . . . One should automate successes, not failures."[11]

Part of this inefficiency, according to Drucker, results from the steady growth of the invisible cost of government: "It is a real cost in money and, even more, in capable people, their time, and their efforts. The cost is invisible, however, since it does not show in governmental budgets. . . But it needs to be taken into consideration before a new policy or a new measure is enacted—and today it is not taken into account in any country (except perhaps in Japan) or by any policymaker." [12]

Straussmann feels we have been able to maintain an inefficient information sector because there is not yet a strong global market for information services: "If and when it comes, the present accumulation of unproductive practices in the U.S. will create a massive upheaval, exceeding in severity what we have so far experienced in the decline of industrial America".

He recommends that: (1) Congress redirect some of its attention from the problems of manufacturing industries to problems of the service sector; and (2) the National Science Foundation sponsor studies of the factors affecting productivity gains and losses by the information workforce. In addition to considering the effects of technology on productivity, the studies would assess the impact of Congressional policies such as the Tax Reform Act of 1986.[13]

Lawrence also pointed out the need to increase productivity in the service sector:

> . . . if you look since 1973, what is striking is that productivity growth in goods areas has not done all that badly. In fact, it now looks in the last few years that we have re-

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[11] Hearing before the Technology Policy Task Force of the Committee on Science, Space, and Technology, 100th Congress, First Session, "The Effects of Technological Change on the Labor Force", July 1, 1987, pp. 71, 137, (No. 32).

[12] Drucker, Peter F., *Innovation and Entrepreneurship: Practice and Principles*, New York, Harper & Row, 1985, pp. 253–260.

[13] Hearing before the Technology Policy Task Force of the Committee on Science, Space, and Technology, 100th Congress, 1st Session, "The Effects of Technological Change on the Labor Force", July 1, 1987, pp. 75, 157, (No. 32).

> turned more or less to the historic rate of improvement in manufacturing that we had before 1973. But if we look in the services area, we find there has been literally zero productivity growth over the period.
>
> And that ironically, rather than our international competitiveness, is the biggest drain on our living standards today. Unless we can find a way to improve our services productivity, 60 percent of what we are producing, that is going to be the dominant source of our living standard improvements.
>
> So, I do applaud the quite novel notion that we should not simply be looking at the goods area. And indeed, what is striking is how little research and development expenditures takes place in services production. Almost all our research and development is taking place in manufacturing. Why aren't we spending on research and development for services? We know abysmally little about the slowdown in services productivity.
>
> And again I applaud the notion that the National Science Foundation ought to be appointing a commission to investigate and to mobilize the kind of knowledge that we may well put in battle against cancer. It is just as important if you will, from the standpoint of our future that we learn what works and what doesn't in this huge proportion of our economy where our productivity growth has been so poor.[14]

However, as previously stated, data received from the service sector is not yet sufficiently accurate to provide a sound basis for decision making. As Ginzberg mentioned: "We don't know how to measure productivity in services." [15]

CONCLUSIONS

1. The United States has had considerable success in creating jobs in the service sector. While there are early indications that the service sector is no more vulnerable to a recession than is the manufacturing sector, the service sector may not be a safeguard against a weak economy.

2. The transition from manufacturing to services has been a long-term trend in industrialized nations. At least in part, this transition stems from increased productivity in the manufacturing sector. But it is important to distinguish between shifts to service

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[14] Ibid., p. 147.

[15] Ibid., pp 71, 137.

industries resulting from rising productivity and those which stem from "abandoning production to others".

3. Trade in services is small compared to trade in goods but it is of considerable importance internationally. While the United States runs a positive trade balance in services in many regions of the world, there are competitive threats comparable to those we have seen in manufacturing.

4. More accurate data on service industries is needed to provide a sound basis from which to form public policies with respect to trade in the service sector.

5. The productivity of American service industries can be expected to affect our balance of trade. Although manufacturing productivity has increased, some analysts conclude that productivity in the service sector is low.

CHAPTER 3—CONSTRUCTION

ISSUES

Construction projects in the U.S. and abroad that have previously been done by U.S. firms are being contracted to foreign-owned firms. Increasingly large quantities of "offshore" prefabricated structures, mechanical systems, electrical devices, and basic building materials are being imported. Architectural and engineering services are being lost to foreign competition. Foreign construction firms, largely supported by government funds, are investing more heavily in research and development than U.S. firms; therefore, U.S. firms are gradually losing their competitiveness in construction technology.

BACKGROUND

In 1986 alone the U.S. construction industry had sales of $375 billion at home and abroad. U.S. construction volume ranges between $330 billion and $390 billion and is about 25 percent of the world's total. This included residential and nonresidential buildings, industrial and utility plants, transportation facilities, water and sewer construction projects and others. Each year about $1,430 billion is spent worldwide on construction giving construction over 10 percent of the world's GDP.

The well being of the construction industry directly affects the American economy. It is one of the major indexes we watch when we are trying to determine whether the economy is getting better or worse. When construction declines, it adversely affects a wide range of workers in a host of different capacities. Masons, carpenters, electricians, painters as well as those who produce the materials and produce the mechanical equipment used in construction are all affected. In the U.S. construction employs 5.5 million people with new building constituting 9 percent of the GDP.

Statistics show a 20-year downward trend in the productivity of the U.S. construction industry. Construction's share of the GNP has fallen, and the volume of U.S. construction abroad has sharply declined. In 1986 U.S. contractors captured $22.6 billion of the $74 billion in international construction that was open to bids. However, since 1983 construction abroad by U.S. firms has declined by 40 percent. The number of foreign countries acquiring U.S. design and construction firms has been increasing as has the the number of foreign firms acquiring construction contracts in the United States.

> Research and development is also a problem. The construction industry in the U.S. is divided into many small firms with little or no research and development capability. The U.S. construction industry invests far less in research as a percentage of sales than almost any other industry in the U.S.[1]
>
> Construction is a major U.S. industry contributing 8.9 percent of the gross national product, ⅔ of the nation's fixed reproducible wealth and it affects everyone's safety, productivity and quality of life.[2]
>
> There is no larger stock holder in construction than the Federal Government who spent $50 billion on construction in 1985. This figure does not include approximately $80 million in loan guarantees, grants, subsidies, insurance programs, and other forms of federal participation in construction financing.[3]

Competitive State of Construction Industry

Between 1920 and the early 1960s, construction productivity grew at a healthy rate of 3.4 percent per year. This sizeable increase in productivity and corresponding decrease in the real cost of construction were due to mechanization of construction technology. The primary motivation behind this technological advance appears to have been the expansion and stability of the highway construction market beginning with the enactment of the Federal Aid Program of 1916 and culminating with the passage of the Highway Trust Fund in 1956.

In the U.S. construction industry the traditional strength has been technology. For the industry to overcome competitive barriers worldwide, it must regain and reassert its technological preeminence. Unless the U.S. construction industry improves its technological standing, it is in danger of being overtaken by international competition before the end of this century.

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[1] House Science, Space, and Technology Committee Hearing on *Research and Competitiveness in the Construction Industry*, Honorable Doug Walgren, June 4, 1987.

[2] Ibid., Dr. Richard N. Wright, Director, Center for Building Technology, NBS.

[3] Ibid., Dr. David Haviland, Dean of the School of Architecture, Rensselaer Polytechnic Institute, Chairman, National Academy of Science Committee on Construction Productivity.

In 1985, $7.3 billion of U.S. construction contracts went to 59 foreign contractors for a 27 percent increase over 1984, and more than double the amount in 1983. It isn't only the construction firms who are not getting the business, but also the architecture and engineering and other services are going offshore as well.[4]

In 1985 Japanese firms accounted for $1.7 billion in construction in the U.S. More than 70 percent of this was work done for their clients or joint ventures in which they were involved. Two German firms accounted for $1.9 billion in contracts that same year.

> Imports of foreign offshore building materials are rising roughly 11 percent annually, while U.S. exports are rising at less than 5 percent.[5]

The $272 million trade surplus in 1981 for nine of the major construction materials became a $872 million deficit in 1985.

> Of the cement used for construction in the U.S., 65 percent either comes in from offshore or is controlled by offshore interests. About 90 percent of the steel bolts and fasteners used in the United States are manufactured abroad.

The Canadians have concentrated in the shopping center market here in the United States and just five Canadian companies own 17 percent of the U.S. shopping center space.[6]

The Canadians have not made large scale purchases of U.S. architectural and engineering design firms. They have simply opened offices and proceeded to accommodate the major Canadian developers which have major projects in this country. Foreign penetration of the domestic architectural and engineering design market is on the rise. Foreign interests buy a major share in well known major American firms. Acquisition or merger seems to be the easiest, most efficient, and most profitable way to enter the U.S. market. In the past five years, British, French, Swiss, West German, Dutch, Lebanese and Saudi interests have all entered our market by purchasing interest in U.S. A&E firms.

> The Japanese have quietly entered the U.S. market in a major and different way. The form of entry is by the very large Japanese construction firms who come in and offer

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[4] Ibid., Dr. Fred Moavenzadeh, Director, Center for Construction Research and Education, MIT.

[5] Ibid.

[6] Ibid.

design, building, and financing services. To date, the Japanese have used American architects for local projects, sometimes to do the design. But more and more the design is going to be done by their enormous architectural and engineering staffs back in Japan, and then shipped here to be built.[7]

The international market share for U.S. architects and engineers is rapidly decreasing. Without question, the number one obstacle overseas is foreign government subsidization of their own national firms. Massive subsidy programs are offered design firms from Japan, Korea, West Germany, France, the U.K., Holland and Spain. And this gives them an overwhelming advantage over their U.S. counterparts and competitors.[8]

U.S. architects and engineers are losing the trade battle, both at home and abroad. U.S. design firms now get foreign business in only two situations; where they have an excellent reputation, and technological advantage. Our technological advantage is diminishing rapidly as foreign firms joint venture with U.S. design firms and learn our technology.[9]

Inferior Foreign Products

Counterfeit products from abroad are increasing. Not only are there concerns about structural steel, but vinyl siding, which bears false markings of evaluations and assessments by some of our model code organizations, has been found. Electrical products and equipment which imitate some popular selling high grade U.S. products, and which bear the underwriters label (UL), are also being imported.[10]

U.S. Construction Research and Development Status

The total annual U.S. investment in construction research and development is low. An estimate that counts as research and development, work which is only marginally or peripherally related to construction yields an annual estimate of $1.2 billion. Only a small portion of this, about $54 million, is contributed by construction contractors. If one includes the entire civil engineering program of NSF, about $220 million comes from federal agencies, and the remaining $800 million comes from manufacturers of construction products and equipment. Much of that contributed by manufacturers is indirect, that is, it's done in other industries for purposes other than construction and has second order benefits to construction.

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[7] Ibid.

[8] Ibid., Mr. R.A. Henry, President and Chief Executive Office of the National Institute of Building Sciences.

[9] Ibid., Mr. Harold L. Adams, President RTKL Associates, representing the American Institute of Architects.

[10] Ibid. Dr. Field Moavenzaden, Director, Center for Construction Research and Education, MIT.

Part of the problem is the small size of many of the U.S. construction firms which limits the funds available for research and development investment. In the absence of construction research and development cooperatives, any small construction firm doing research and development would likely be duplicating the work of others. In the area of home energy conservation every home owner must become an energy efficiency expert in order to apply the best energy savings technology.[11]

> Support of research and development, no matter how funded provides a technological edge for the United States. The new processes, the new products developed provide additional opportunities for the U.S. construction industry, both here and abroad. Broad research and development support should be a major effort, not only of our government, but all segments of our economy. The government should foster and support more research and development in the construction field.[12]
>
> The U.S. investment in construction research and development is 0.39 percent of total construction sales. This industry invests proportionately less in research and development than most other mature U.S. industries. Based on the lack of increase in U.S. construction productivity over the last 20 years and the low rate of investment in research and development, the National Academy of Sciences Committee on Construction Productivity concluded that construction related research and development has been inadequate and needs to be increased.[13]

Contractors, architects, and engineers contribute less than 0.05 percent of total construction sales to research and development, yet they're spending in excess of four percent of construction sales or 80 times as much on liability insurance. The major Japanese construction firms are each investing more in research and development than our total private sector. The Japanese have been investing one percent of their gross construction sales in research and development for the past five or six years.[14]

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[11] Mr. Anthony E. Scoville, Consultant in Science and Engineering Policy to Congressman George E. Brown, Jr.

[12] Ibid., Mr. Kenneth Roe, Chairman and Chief Executive Officer of Burns and Roe Enterprises.

[13] House Science, Space, and Technology Committee Hearing on *Research and Competitiveness in the Construction Industry*, June 4, 1987. Testimony by Dr. David Haviland, Dean of the School of Architecture, Rensselaer Polytechnic Institute, Chairman, National Academy of Sciences Committee on Construction Productivity.

> Our analysis indicates that if American companies were to pursue their own sources of technical expertise internally by operating, for example, research and development laboratories—none of them do, in sharp contrast to their Japanese competitors—they would be in better shape. They would also be in better shape when it comes to fending off the inroads into the U.S. construction market, which, of course, is the biggest by far in the world. But foreign construction firms are targeting our market because they now have the tools to compete here.[15]

Areas of Construction Industry Where Technology Competition Is Growing

Japanese and European industries continue to develop technologies in many areas of construction.

The Japanese and the Germans have done significant work on smart cranes. And the Japanese tunneling machinery is an example of offshore research and development in those areas that we frequently have only put into practice after we can purchase it from them.[16]

We see in the Japanese laboratories in a great deal of work in developing such things as the slurry shield tunneling method, a method of tunneling that is much more efficient in certain types of soils than conventional tunneling methods. This technology is now winning the Japanese construction jobs here and in other countries.[17]

We see very large shaking tables available in Japan that we don't have here in the U.S. The Japanese are developing and verifying nuclear reactor systems that will give them substantial benefit in competition for providing these facilities to third world countries.

In Japan we see work on developing base isolation systems for earthquake resistant buildings. They have built verification and testing facilities for these structures that we don't have available here in the U.S.

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[14] Ibid., Dr. John Fisher, Professor of Civil Engineering, Lehigh University, Director of the Engineering Research Center Advanced Technology for Large Structural Systems.

[15] Hearing, *Technology and Economics in a Shrinking World*, before the Technology Policy Task Force of the Committee on Science, Space, and Technology, House of Representatives, October 22, 1987. Testimony by Dr. John A. Alic, Senior Associate, Office of Technology Assessment.

[16] House Science, Space, and Technology Committee Hearing on *Research and Competitiveness in the Construction Industry*, Dr. John Fisher, Professor of Civil Engineering, Lehigh University.

[17] Ibid., Dr. Richard N. Wright, Director, Center for Building Technology, National Bureau of Standards.

Die casting technology for small power tools is an area of technology in which the Japanese have a substantial edge.[18]

Areas of United States Construction Industry Where Research and Development Are Needed

Research is needed to automate construction, to improve energy efficiency, to develop better bridge designs, and inspection methods, and to cut construction costs.[19]

The technology base is not adequate for really efficient and thorough inspection of bridges in a cost-effective way. A great deal needs to be done to develop non destructive inspection techniques that let us find hidden flaws. Flaw detection in concrete is one of the high priority areas.[20]

As we look to the next century, we should develop and use sensors that could be permanently installed on bridge structures that would monitor them and tell us what is going on. Work is needed in the areas of corrosion detection and crack detection. I think there are major problems with the way bridge inspections are done and I think we are making a mistake having mandatory bi-yearly or every two-year inspection periods. I think we are wasting resources and I would personally prefer to see resources more focused on using sound engineering judgments and calculations.[21]

Computers, especially in the form of artificial intelligence and knowledge based systems, automation, robotics, remote sensing and remote control and engineered synthetic materials have advanced far enough that they are poised to penetrate the construction industry and create an exciting new era in construction.[22]

Computer based integration in the manufacturing industries is well underway in the U.S. However, there is no effort of any significance currently underway in the U.S. construction industry. This technology needs to be developed through systematic research.[23]

The National Bureau of Standards has a major research program in construction. They work closely with industry, universities, other government agencies, and those who will use the results to assure that the work is on target and timely.

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[18] Ibid.

[19] Ibid., Honorable Sherwood L. Boehlert.

[20] Ibid., Dr. Richard N. Wright, Director, Center for Building Technology, National Bureau of Standards.

[21] Ibid., Dr. John Fisher, Professor of Civil Engineering, Lehigh University, Director of the Engineering Research Center Advanced Technology for Large Structural Systems.

[22] Ibid., Dr. David Haviland, Dean of the School of Architecture, Rensselaer Polytechnic Institute, Chairman, National Academy of Sciences Committee on Construction Productivity.

[23] Ibd., Dr. John Fisher, Professor of Civil Engineering, Lehigh University, Director of the Engineering Research Center Advanced Technology for Large Structural Systems.

Japan Housing Industry-Advanced Technology

> . . . American housing manufacturers make highly standardized, low-cost products for the low end of the market. In contrast, Japan's five leading prefab-house makers—Sekisui House, Daiwa House, National House, Misawa Homes, and Sekisui Chemical (which owns about 20 percent of Sekisui House, but also produces homes using its own manufacturing system)—have each developed a computer-aided design and manufacturing system to tailor new houses to a purchaser's needs.
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> . . . James McKellar, Director of MIT's Center for Real Estate Development, says Japanese housing makers, typically spend 1.5 percent of their income on research to create features and high-quality materials unavailable in prefabricated houses made in the United States.
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> . . . McKeller says savings from mass production represent only a small share of the price of a house. In most cases, land, regulatory approvals, site preparation, design, materials, and similar factors account for far more of a house's final cost than does on-site labor.
>
> . . . Japanese companies also present entire bathrooms out of tough, water-proof, easy-to-clean plastic. The Sekisui Group and National Home are among the leaders with these systems.
>
> Both Sekisui Home and National Home build one-piece walls of aluminum and foam—inexpensive materials that provide good insulation. Misawa Home makes ceramic wall panels to replace concrete. Although the panels use the same raw materials as concrete, the Japanese carefully control baking and air injection to create a lighter, better-insulating, and at least potentially cheaper wall material. The Japanese have also created systems to ensure excellent ventilation without heat loss. Kobori Construction, a smaller firm, has developed two-story panels made of an egg-carton-like plastic to efficiently insulate the home while allowing moisture to escape into air channels that vent through the roof.
>
> Perhaps most importantly, Japanese prefabricated-housing makers have adapted quality-control techniques originally developed for the automotive and appliance industries. "The great dilemma we face in the housing industry", says McKellar, a former home builder in Canada, "is that your

work is only as good as the particular laborer you hire. You can't impose a system of quality control when you're constructing everything on-site and the construction has to be adapted to the weather and the mood of the craftsman".

The Japanese ensure predictability by doing most of their work in carefully controlled factories. For example, the lifespan of a typical roof built on-site in the United States can vary considerably, averaging perhaps 20 to 30 years. According to McKellar, Japanese manufacturers confidently predict that their roofs, which include a tough, sealed plastic membrane and are built entirely at the factory, will last as long as 50 years.

But exporting houses is not easy, and dramatic adaptations would be required to meet U.S. needs. Instead, several of the major Japanese manufacturers, notably Misawa, are looking to license their techniques abroad.

McKellar sees possibilities for Japanese techniques in the United States, but worries about the cyclical nature of the U.S. home building industry. Traditionally, the extreme volatility of that market has led U.S. builders to conserve capital by sticking to low-technology construction: Without the kind of long-term financial support provided by the Japanese Government, the American dream may not include high-quality manufactured housing.[24]

CONCLUSIONS

The construction industry has failed to make the necessary investments in research and development to keep up with other industrial nations, especially in the area of prefabrication, large modular unit equipment, and advancements in construction equipment

These shortcomings, along with archaic government contracting procedures is limiting the ability of the U.S. to keep up with housing and some public works, such as mass transit systems.

The fragmented nature of the construction industry is not conducive to strong research and development programs. In fact, the industry relies heavily on equipment manufacturers and, therefore, is not able to act as a single entity.

In the Recommendations section of this report, the Task Force recommends that government sponsor a major program in construction Research and Development.

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[24] Robert Chapman Wood, *Prefab House Made Upscale, New Technololgy Eradicates a Low-End Image, High Technology Business*, January 1988, p. 15.